REMEDIAL INVESTIGATION REPORT
AREAS OF INTEREST 1, 2, 3, AND 4

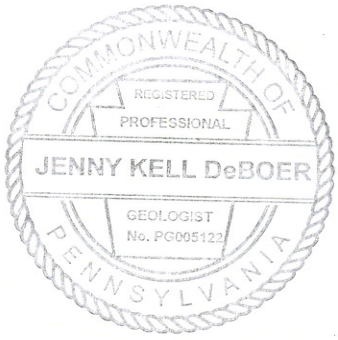
Sunoco Partners Marketing and Terminals LP
Marcus Hook Industrial Complex
100 Green Street, Marcus Hook Borough and Lower Chichester Township, Delaware County, Pennsylvania
Sitewide PADEP Facility ID No. 780192
Area of Interest 1 PADEP Facility ID No. 778391
Area of Interest 2 PADEP Facility ID No. 778392
Area of Interest 3 PADEP Facility ID No. 778394
Area of Interest 4 PADEP Facility ID No. 778395

Stantec

Prepared for:

Marcus Hook Refinery Operations,
a series of Evergreen Resources Group, LLC

Prepared by:
Stantec Consulting Services Inc.



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ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
ACGIH	American Conference of Governmental Industrial Hygienists
AOC	Area of Concern
AOI	Area of Interest
AST	aboveground storage tank
$CaCO_3$	calcium carbonate
CAP	Corrective Action Process
CBI	Chicago Bridge & Iron
CCR	Current Conditions Report
cm/s	centrimeter per second
cm^3S/g	cubic centimeters second per gram
CRP	Community Relations Plan
CSM	conceptual site model
COC	constituent of concern
CORMIX	CORMIX Mixing Zone Model
Crompco	Crompco Corporation
DELCORA	Delaware County Regional Water Quality Control Authority
DNAPL	dense non-aqueous phase liquid
EDB	1,2-dibromoethane
EDC	1,2-dichloroethane
EPA	United States Environmental Protection Agency
ERM	Environmental Resources Management
ETP	Energy Transfer Partners, L.P.
Evergreen	Marcus Hook Refinery Operations, a series of Evergreen Resources Group, LLC
FCCU	Fluid Catalytic Cracking Unit
f	Fill
ft	feet
ft bgs	feet below ground surface
ft/d	feet per day
ft^2/day	square feet per day
ft/ft	feet per foot
GIS	graphic informational system
gpm	gallons per minute
HHRA	Human Health Risk Assessment
H_2S	hydrogen sulfide
k	hydraulic conductivity
LDRM	LNAPL distribution and recovery modeling
LiDAR	Light Detection and Ranging
LNAPL	light non-aqueous phase liquid
LCO	light cycle oil
LCSM	LNAPL Conceptual Site Model
LPG	Liquefied Petroleum Gas
mg/kg	milligrams per kilogram
ml/min	milliliters per minute
µg/l	micrograms per liter
$µg/m^3$	micrograms per cubic meter
MHIC	Marcus Hook Industrial Complex
MFA	Multifunctional Additive
MSC	Medium Specific Concentration
MTBE	methyl tert butyl ether
NAVD 88	North American Vertical Datum of 1988

NESHAP	National Emission Standards for Hazardous Air Pollutants
NJDEP	New Jersey Department of Environmental Protection
NJGS	New Jersey Geological Survey
NIOSH	National Institute for Occupational Safety and Health
NIR	Notice of Intent to Remediate
NORR	Notice of Reportable Release
NOWData	National Weather Service Online Weather Data
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
PADCNR	Pennsylvania Department of Conservation and Natural Resources
PADEP	Pennsylvania Department of Environmental Protection
PAFBC	Pennsylvania Fish and Boat Commission
PaGWIS	Pennsylvania Groundwater Information System
PCB	polychlorinated biphenyl
POTW	Publicaly Owned Treatment Works
PDH	propane dehydrogenation unit
PEL	Permissible Exposure Limit
PGP	polymer grade propylene
PID	Photoionization Detector
PNDI	Pennsylvania Natural Diversity Inventory
PPE	Personal Protective Equipment
ppm_v	parts per million by volume
PSG	passive soil gas
RCRA	Resource Conservation and Recovery Act
RCRA metals	RCRA 8 metals
R&D	Research & Development
REL	Recommended Exposure Limit
RIR	Remedial Investigation Report
RSL	Regional Screening Level
SHS	Statewide Health Standard
SPH	Sphere
SSS	Site-Specific Standard
SPMT	Sunoco Partners Marketing and Terminals L.P.
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
SVGW-NR	PADEP Groundwater Site Specific Standard Vapor Intrusion Screening Values, Non-Residental
SVGW-R	PADEP Groundwater Site Specific Standard Vapor Intrusion Screening Values, Residental
SVIA-NR SHS	PADEP Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential
SVIA-NR SSS	PADEP Indoor Air Site Specific Standard Vapor Intrusion Screening Values, Non-Residential
SWMU	Solid Waste Management Unit
SWF	Solid Waste Facility
1,2,4-TMB	1,2,4-trimethylbenzene
1,3,5-TMB	1,3,5-trimethylbenzene
THQ	Target Hazard Quotient
TDS	total dissolved solids
TK	Tank
TR	Target Risk
TLV	Threshold Limit Value
USGS	United States Geological Survey
UST	underground storage tank

VGO	vacuum gas oil
VI	vapor intrusion
VOC	volatile organic compound
Work Plan	Work Plan for a Site Wide Approach

1.0 Introduction

Stantec Consulting Services, Inc. (Stantec) has prepared this Remedial Investigation Report (RIR) for Area of Interest (AOI) 1, 2, 3, and 4 on behalf of Marcus Hook Refinery Operations, a series of Evergreen Resources Group, LLC (Evergreen) regarding the Sunoco Partners Marketing and Terminals L.P. (SPMT) Marcus Hook Industrial Complex (facility), formerly Marcus Hook Refinery, located at 100 Green Street in Marcus Hook, Delaware County, Pennsylvania (**Figure 1-1**). Sunoco, Inc. (R&M) previously operated the facility, which is currently owned by SPMT. As of December 30, 2013, Evergreen assumed the responsibility for remediation liabilities occurring at the facility on or before April 1, 2013.

1.1 FACILITY DESCRIPTION AND CURRENT USE

The subject property is located on the north bank of the Delaware River in the Borough of Marcus Hook, Delaware County, Pennsylvania, with portions of the facility in Lower Chichester Township, Pennsylvania and Claymont, New Castle County, Delaware (See **Figure 1-2**). The facility frontage extends approximately 4,800 feet (ft) along the northern banks of the Delaware River. The facility, which is located on industrial property, covers approximately 585 acres of land with access restricted by fencing and security measures.

The area surrounding the subject property is characterized by a mixture of residential, commercial, recreational, active industrial, and vacant industrial properties and is bordered on the south by the Delaware River (**Figure 1-2**). Several underground utilities, maintained by the Marcus Hook Borough and Lower Chichester Township, are present in the roadways bordering the property. Sanitary sewer and storm water sewer systems are present onsite.

The facility is currently operated by SPMT which is transitioning the former Marcus Hook Refinery into an operation referred to as the SPMT Marcus Hook Industrial Complex (MHIC). Current operation of the facility (24 hours per day) includes the processing and storage of light hydrocarbon products plus support facilities. Support facilities include a flare, a wastewater treatment area, boilers, air compressors, loading and unloading facilities, and the production of racing gasoline. SPMT is retrofitting the property with new facilities to process, store, chill, and distribute propane and ethane. A portion of the facility known as Phillips Island is occupied by a combined-cycle, co-generation, and natural gas-fired power plant owned and operated by a subsidiary of NextEra Energy Resources. Sunoco LP maintains a portion of the facility for race fuels (Sunoco Race Fuels). Braskem leases the polypropylene plant (AOI 8) and the propylene splitter at 15-2 (AOI 5) along with various ancillary piping, storage, and loading.

SPMT receives, stores, and fractionates natural gasoline (feedstock), as well as stores and transfers the two fractionation products, pentane (overheads product) and light naphtha (bottoms product) at the depentanizer unit (C5 Splitter) at the MHIC. The products are shipped offsite via truck, pipeline, and/or barge. The 15-2B T-05 fractionation unit (depentanizer) is operated with a maximum natural gasoline feed rate of 20 thousand barrels per day. SPMT utilizes four storage tanks for feedstock storage (Tanks 607, 609, 610, and 611), three storage tanks for bottoms product storage (Tanks 246, 250, and 253), and three spheres for overheads product (SPH-3, SPH-4, and HS-16).

SPMT also receives, stores, and fractionates a liquefied ethane/propane transmix (feedstock), as well as stores and transfers the two fractionation products, ethane (overheads product) and propane (bottoms product) at the MHIC. This deethanizer unit is operated with a maximum propane/ethane transmix feed rate of 80 thousand barrels per day. SPMT currently utilizes one cryogenic tank for ethane storage (TK 401) and one cryogenic storage tank for propane storage (TK 101). The ethane and propane products are shipped offsite via marine vessels.

SMPT also transports and provides terminalling services for crude oil and refined products at MHIC. Crude oil and refined products (i.e. butane, alkylate, etc.) are received at the MHIC via barge, rail car, pipeline, and/or truck and temporarily stored in bulk storage tanks and caverns to facilitate movements to other transportation systems.

There are several tenants onsite utilizing steam, flare, fuel gas, wastewater treatment, air, water, and other utilities and services. The tenants include fractionation, conversion, and blending operations for a variety of products, including Sunoco Race Fuels and power to the grid.

Currently the site is undergoing major redevelopment in association with the Mariner East projects and other infrastructure changes. Much of the infrastructure associated with the former refining operations has been decommissioned and demolished including the 10 Plant operating area (AOI 1) and the 12 Plant operating area (most of AOI 2). SMPT's future plans include providing separation of transmix or deethanized natural gas liquids into export grade propane, mixed butane, and natural gasoline in 2017 and installation of a propane dehydrogenation (PDH) unit to produce polymer grade propylene (PGP) at the MHIC utilizing propane feedstock from natural gas liquids.

1.2 REGULATORY SETTING

In order to fulfill the notification requirements under Act 2, a Notice of Intent to Remediate (NIR) for the facility was submitted to Pennsylvania Department of Environmental Protection (PADEP) on September 15, 2011 (**Appendix A**). The NIR expressed the intent of Sunoco, Inc. (R&M) to enter the facility into the One Cleanup Program with PADEP and Environmental Protection Agency (EPA) in order to satisfy the requirements of both the corrective action obligations under Resource Conservation and Recovery Act (RCRA) and state requirements under the Land Recycling Program (Act 2)(PADEP, 2002). In a letter received November 8, 2011 (**Appendix A**), PADEP and EPA acknowledged this intent, and the facility was officially entered into the One Cleanup Program. The One Cleanup Program will serve as the regulatory program for site-wide remedial activities at the facility. One Cleanup Program activities undertaken in portions of the facility situated in Pennsylvania will be performed under the regulatory lead of the PADEP. Site characterization and remediation activities undertaken in portions of the facility situated in Delaware will be performed under the regulatory lead of the EPA. Sunoco, Inc. (R&M) submitted a Work Plan for a Site Wide Approach (Work Plan) to the PADEP and the EPA on December 19, 2011 to serve as a roadmap to navigate the facility through the site characterization and remediation process to achieve site closure (Langan Engineering and Environmental Services, Inc [Langan], 2011). As part of this Work Plan, Sunoco, Inc. (R&M) originally divided the facility into seven AOIs based on operational areas and risk-based factors including product types, potential exposure pathways, receptors,

known light non-aqueous phase liquid (LNAPL) quantities, and historical information. The Work Plan also presented a schedule to characterize each of the seven AOIs. Dependent upon the results of future investigation activities, these AOIs may be further refined based on site conditions, receptors, and/or other factors. The boundaries of AOIs 5 and 7 were revised in 2012. AOI 8 was added in 2013, but was removed from the Act 2 program in 2016 (**Figure 1-2**). An updated NIR was submitted in January 2015 in order to update the facility ownership and remediation requirements (**Appendix A**).

On January 30, 2012, Sunoco, Inc. (R&M) submitted a Current Conditions Report and Comprehensive Remedial Plan (CCR) for the facility (Langan, 2012a). This was the first report submittal under the Work Plan. The CCR served as an initial assessment of the facility and drew its information from a variety of sources including historical reports, employee accounts, regulatory history, and onsite preliminary observations. The purpose of the CCR was to summarize known current and historical environmental conditions at the facility and to provide a basis for site characterization and remedial plan for the facility going forward. The CCR presented a detailed Conceptual Site Model (CSM) based on available historical information and review of historical environmental reports. The CCR also included a discussion of Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) listed in the 1991 Phase II RCRA Facility Assessment Report (1991 Phase II RFA) (A.T. Kearney, 1991).

AOI 6 was identified as the first AOI for characterization, and the RIR for AOI 6 was submitted to the PADEP on September 30, 2012 (Langan, 2012b). This RIR for AOIs 1 through 4 will be the second RIR submitted under the Work Plan.

Evergreen, Stantec, and Langan have had multiple meetings with PADEP and EPA representatives to review the proposed characterization activities for AOIs 1 through 4, and activities have been implemented by Evergreen between 2013 and 2016.

1.3 FACILITY OPERATION HISTORY AND PREVIOUS INVESTIGATIONS

The facility has a long history of petroleum transportation, storage, and refining of fuels and petrochemicals. Operations began in 1902, and the facility was owned and operated by Sunoco since its inception as Sun Oil in 1901. On December 1, 2011, Sunoco, Inc. (R&M) announced the indefinite idling of the main processing units at the facility due to deteriorating refining market conditions. On October 5, 2012, Energy Transfer Partners, L.P. (ETP) and Sunoco, Inc. (R&M) announced the merger of a wholly owned subsidiary of ETP. The Marcus Hook Property was transferred to SPMT on April 1, 2013.

The following sections provide descriptions of each of the four AOIs addressed in this RIR, as well as area-specific operational history summaries.

1.3.1 Area of Interest 1: 10 Plant

AOI 1 is bordered by Ridge Road to the northwest, Green Street to the northeast, the Amtrak/Norfolk Southern Railway to the southeast, and Hewes Avenue to the southwest (**Figure 1-2**). AOI 1 encompasses approximately 30 acres.

AOI 1 historically contained the 10-4 Catalytic Cracking Unit which is located northwest of the Amtrak/Norfolk Southern Railway. The primary purpose of the 10-4 Catalytic Cracking Unit was to split long chain hydrocarbons into high octane compounds for gasoline and fuel oil blending. Spent catalyst fines were collected in an emission control system and the feedstock was separated at the distillation plants (A.T. Kearney, 1991). Furnace oil driers, the propane loading rack, and numerous above and below grade pipelines also existed in AOI 1 (GES, 1995). The main buildings in AOI 1 consisted of the 10 Plant Control Room, Supervisors Building, and Zone Shop Building. In December of 2011, refining operations and units were idled, and permanent decommissioning of the 10-4 unit began in 2014. Demolition of the unit was completed in early 2015, and the area is currently being used to store/stage materials for the Mariner East projects being completed elsewhere onsite. A few structures, including the Men's Building near the eastern corner of the AOI, remain in place.

Based on the 1991 Phase II RFA, ten SWMUs were identified within AOI 1. These SWMUs are either within or immediately around the former location of the 10-4 Catalytic Cracking Unit. The approximate locations of these SWMUs are shown on **Figure 1-3**:

- SWMUs 35–39: 10-4 Plant Catalyst Fines Collection Roll-Offs
- SWMU 40: 10-4 Plant Roll-Off Storage Area
- SWMU 41: 10-4 Spent Catalyst Silo
- SWMU 42: 10-4 Plant Electrostatic Precipitators
- SWMU 43: 10-4 Plant Sour Water Stripper
- SWMU 44: 10-4 Plant Catalyst Regeneration Unit

Historically, the 10 Plant Tankage Area existed to the northwest of the 10-4 Fluid Catalytic Cracking Unit (FCCU) (A.T. Kearney, 1991). Based on a review of historical aerial photographs dating back to 1937 included in the CCR submission, it appears most of the aboveground storage tanks (ASTs) in 10 Plant Tankage area were removed by the late 1980s. Several processing facilities and buildings throughout AOI 1 also appear to have been removed from AOI 1 by the late 1980s. Several waste management activities were related with the 10-4 Plant which included the FCCU. The catalyst used in the FCCU was continually regenerated in the 10-4 Plant Catalyst Regeneration Unit (SWMU 44) and when spent catalyst was removed from the system, it was stored in the 10-4 Plant Spent Catalyst Silo (SWMU 41) prior to transport to the 10-4 Plant Roll-Off Storage Area (SWMU 40).

1.3.2 Area of Interest 2: 12 Plant

AOI 2 is bordered by West 10th Street (also referred to as Post Road, Philadelphia Pike and State Route 13) to the northwest, Green Street to the northeast, Chester & Delaware River Railroad to the southeast, and the Middle Creek Conveyance to the southwest (**Figure 1-2**). AOI 2 encompasses approximately 35 acres.

Historically, AOI 2 consisted mainly of the 12 Plant processing unit. The 12-3 Crude Unit was located in the central portion of AOI 2 and processed crude via atmospheric and vacuum distillation (A.T. Kearney, 1991). In December of 2011, refining operations and units were idled, and permanent decommissioning of the 12-3 unit began in 2014. Demolition of the unit was completed in early 2015, and the area is currently

being used as a parking lot for facility contractors. The northern portion of the AOI is currently occupied by Sunoco Race Fuels which operates a fuel blending plant, ASTs, and truck loading facilities. Railroad lines are located in the southern and western portion of AOI 2. Bordering the western boundary of AOI 2 is the Middle Creek stormwater conveyance feature which will be discussed in additional detail in **Section 2.3.1**.

Based on a review of the historical aerial photographs, several processing facilities, buildings, and ASTs were decommissioned by the late 1980s. According to the 1991 Phase II RFA, three SWMUs were identified within AOI 2. One of these, the 1C Oil/Water Separator (SWMU 65), is located on the western side of the Middle Creek conveyance in AOI 5 and will be characterized during the remedial investigation for AOI 5. **Figure 1-3** depicts the approximate location of each SWMU:

- SWMU 25: 12 Plant Sludge Basin
- SWMU 83 : 12A Oil/Water Separator

The 12 Plant Sludge Basin is located in the western portion of AOI 2 between the Middle Creek conveyance and the railroad tracks. This unlined sludge basin was used from the 1920s to the 1940s for the disposal of acid sludge and tar. Environmental investigations were completed in the 1950s and the 1990s to further characterize and delineate the sludge basin (**Appendix B**). Two primary fill materials were encountered consisting of black tar in most areas of the basin and black sludge located in the southern end of the basin (A.T. Kearney, 1991). A series of test borings and test pits were completed by Environmental Resources Management (ERM) in 1990 to further delineate and characterize the basin (**Appendix B**).

1.3.3 Area of Interest 3: Refinery Office Buildings

AOI 3 is bordered by the Chester & Delaware River Railroad to the northwest, Green Street to the northeast, Delaware River to the southeast, and Hewes Avenue to the southwest (**Figure 1-2**). AOI 3 encompasses approximately 36 acres.

Historically, the 8-C Crude Unit, which processed crude via atmospheric distillation and vacuum distillation, was located in the central portion of AOI 3 (A.T. Kearney, 1991). Located to the southeast of the former 8-C Crude Unit are several buildings including the former Research and Development building, the former Refinery Laboratory, and the Main Office Building. The headquarters building, main facility entrance, and the Semi-Works buildings operated by Sunoco Race Fuels are located near the far eastern portion of the AOI. A contractor parking lot is located in the northern portion of AOI 3, and the main parking lot for the facility is located along the southeastern and southwestern portions of AOI 3 along the Delaware River. Located in the southwest corner of AOI 3 is the No. 1 Wharf Area which is used for docking, loading, and unloading ships.

Based on the 1991 Phase II RFA, six SWMUs and one AOC were identified within AOI 3. **Figure 1-3** depicts the approximate location of each SWMU and AOC:

- SWMU 52: Laboratory Waste Accumulation Building
- SWMU 53: 8-C Crude Unit Drip Showers
- SWMU 57: Clay Contact Plant Area
- SWMU 58: Slop Oil Tank V-29
- SWMU 59: Slop Oil Tank 132
- SWMU 61: Ballast Water Tank W-12
- AOC F: 8-C Polychlorinated biphenyl (PCB) Transformer Area

The former Clay Contact Plant (SWMU 57) was located in the current contractor's parking lot. The Clay Contact Plant was constructed in the 1940s and reportedly shut down operations in 1983 when the production of lubricating oils at the refinery stopped. The clay was used to remove acids, caustics, sulfonates, water, and aromatics from specialty oils and had a hydrocarbon content of approximately 30%.

As shown on **Figure 1-3**, a stone bulkhead existed along the historical shoreline of the Delaware River in 1937. In-filling of land towards the river resulted in two separate expansions and bulkheads (new bulkheads were constructed in 1960 and then later in 1966). The bulkhead constructed in 1966 is the current, existing bulkhead. Spent filter clay, granite, and foundry sand were primarily used to fill in the areas between the bulkheads (Dames & Moore, 1999). The filled in portions of land along the Delaware River in AOI 3 are mainly covered with impervious surface and utilized by the facility as a parking lot area. Based on a review of historical aerial photographs, several large building structures located in the southern portion of AOI 3 were removed by the 1970s. Several ASTs located in the northern portion of AOI 3 were decommissioned by the late 1980s. Groundwater investigation activities completed in 1995 had identified LNAPL in the vicinity of the Laboratory Building. Based on historical groundwater investigations completed, LNAPL in the western portion of AOI 3 had a similar viscosity to LNAPL sampled in AOI 6, suggesting that the plumes from AOIs 3 and 6 were commingling (GES, 1995).

During a partial excavation of a sewer line on November 14, 2000, a steel line was damaged releasing mercury to the surrounding excavation area. An emergency cleanup was conducted which consisted of removal of impacted soil (Handex, 2001). Subsequent site investigation studies however, showed mercury levels detected above the Statewide Health Standards (SHS) at some sampling locations, and mercury was detected in groundwater samples at concentrations exceeding the SHS (Handex, 2001). Based on the conclusions of the 2001 Site Investigation Report prepared by Handex, it was noted that the area of impacted soil by the mercury release remained undefined. Additional work was performed by GES, and a draft report was prepared (GES, 2002). Further investigation was conducted in this area and will be described in this report.

1.3.4 Area of Interest 4: Upper No. 1 Tank Farm, Lower No. 1 Tank Farm, and PP&L Tankage

AOI 4 is the AST field area located northwest of Post Road (**Figure 1-2**) and encompasses approximately 150 acres. Based on a review of historical aerial photographs, the western portion of AOI 4 was primarily undeveloped land until December 1974 when several ASTs were installed in this area. Since 1932, much

of the central portion of AOI 4 has consisted of a tank farm area, with some removal and additions of small buildings, tanks, and units in the eastern portion of AOI 4. By the early 1990s, several ASTs were removed in the northeastern portion of AOI 4. Several ASTs were permanently closed-in-place since that time.

AOI 4 is bisected by the Amtrak/Norfolk Southern Railway into a northwestern and southeastern section. The southeastern section of the Lower No.1 Tank Farm also extends into AOI 5 to the southeast, whereas the PP&L Tankage area and the Upper No.1 Tank Farm comprise the northwestern section. The Upper No. 1 Tank Farm is further divided by Blueball Avenue into the Upper No. 1 Tank Farm West Section, which is sometimes referred to as the Paulson Tank Farm, located to the west of Blueball Avenue, and the Upper No. 1 Tank Farm which is located to the east of Hewes Avenue. The PP&L Tankage extends to the Transcontinental Gas Pipeline which bisects the PP&L Plant Tankage and the Upper No. 1 Tank Farm West Section.

AOI 4 was comprised of several tank farms storing a variety of petroleum products and was the largest AST storage area in the former refinery. Some of the ASTs are still in use, but many have been closed. Numerous aboveground and below ground pipelines were active throughout AOI 4 with some still currently in use. The PP&L Tankage served as No. 6 fuel oil storage and is bound to the west by industrial properties, to the north by Ridge Road, to the east by the Paulson Tank Farm and to the south by the Amtrak/Norfolk Southern Railway. The Paulson Tank Farm served as crude oil storage and is bound on the east by Blueball Avenue, to the west by the PP&L tankage, to the north by Ridge Road, and to the south by the Amtrak/Norfolk Southern Railway. The Upper No. 1 Tank Farm served as vacuum gas oil storage for the former 10 Plant and extends west from 10 Plant (Hewes Avenue) to Blueball Avenue. The Upper No. 1 Tank Farm is bound to the north by Ridge Road and to the south by the Amtrak/Norfolk Southern Railway. The Lower No. 1 Tank Farm consists of several ASTs that house primarily finished product components and distillates. The section of the Lower No. 1 Tank Farm located in AOI 4 extends southeast of the Amtrak/Norfolk Southern Railway to Post Road. Tankage to the south of Post Road is also part of the Lower No. 1 Tank Farm but is located in AOI 5. In the far southwest portion of Lower No. 1 Tank Farm is the Auto Lab Building. Various processing and shipping areas comprise the southeast portions of AOI 4. Walkers Run, which was part of the Middle Creek Stormwater Conveyance system, is located in the northern portion of AOI 4. Two gas-storage caverns (identified as AOC E in the Phase II RFA) also exist in bedrock approximately 400-500 feet below grade in AOI 4 (Langan, 2012a). AOI 4 also contained several underground storage tanks (USTs) located directly north of the Auto Lab. These tanks were permanently closed in November 2010.

The H-5 Plant Unit, which is used as a gasoline blending plant, is located in the southeast portion of AOI 4. The H-5 Control Room is located within the H-5 Plant Unit area. Further to the southeast is the Hardwood Area which contains multiple ASTs. To the north of the Hardwood Area are the Old Grease Plant and the Liquefied Petroleum Gas (LPG) areas. The Blending Building is located in the northern corner of the LPG Shipping Area. Based on the 1991 Phase II RFA, four SWMUs were identified within AOI 4. One of these SWMUs, SWMU 96 – Middle Creek Surface Drainage System, will be addressed during the characterization of AOI 7, as the the creek terminates in AOI 7 at the Delaware River. Approximate locations of the SWMUs are shown on **Figure 1-3**:

- SWMU 63: 1A Oil/Water Separator
- SWMUs 81 and 82: 10A and 10B Oil/Water Separators

The Phase II RFA also identified AOC E, the underground gas-storage caverns, since two of the caverns are located in AOI 4 (**Figure 1-3**). As these were not waste storage units, they will not be addressed under the RCRA corrective action program.

In January of 2000, elevated hydrocarbon concentrations were discovered in several manholes in the northern, westbound lane of Post Road. Emergency remedial actions were completed and consisted of temporary closing of the road, evacuating liquid and vapors from the manholes, and performing investigations to evaluate potential source areas. The subsequent investigations revealed four areas of free product along Post Road. Two of the free product areas coincided with a large number of underground lines. Two total fluids extraction remediation systems , the the H-5 and 12 Tank Recovery Systems, currently exists in this area.

1.4 SELECTION OF CONSTITUENTS OF CONCERN

The list of the primary constituents of concern (COCs) in soil and groundwater for AOIs 1 through 4 is available in **Table 1-1**. The shorter of the two lists, the Evergreen Petroleum Short List, is an updated listing of the COCs originally identified in the Work Plan for the facility under the Pennsylvania One Cleanup Program and will be referred to as the Evergreen Petroleum Short List. This list includes all current constituents from the Short List of Petroleum Products published as Table IV-9 in Chapter VI, Section E of the Land Recycling Program Technical Guidance Manual (PADEP, 2002), with the exception of the waste oil parameters as waste oil is only stored in small tanks within the facility maintenance garages. Historically, as PADEP has made changes to constituents on the Short List of Petroleum Products, the Evergreen Petroleum Short List has been updated accordingly.

In August 2013, a PADEP email suggested a broader list of COCs should be used for site characterization of regulated substances that are not included on the PADEP short list of petroleum products. An expanded COC list consisting of the PADEP Southeast Regional Office's crude oil COC list (Skinner crude list) combined with the Evergreen Petroleum Short List was created for these situations and is included as **Table 1-2** as the Evergreen Comprehensive List of COCs (Evergreen Comprehensive List).

The Evergreen Petroleum Short List remains the primary list of COCs for the site. Analyte lists were expanded to include comprehensive COC list parameters in areas of historical use that included storage or handling of petroleum products not on the PADEP petroleum short lists. Other compounds were added to the analyte lists in particular areas based on use and known releases. One example of this is that the RCRA 8 metals (RCRA metals) list consisting of arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, were added in some SWMU areas. Also, note that in groundwater, all metals referenced indicate the dissolved fraction.

AOI 1

As operations in the 10-4 unit were related to gasoline and fuel oil production, Evergreen Petroleum Short List was chosen as the primary COC list for AOI 1. Additional RCRA metals (arsenic, barium, cadmium, chromium, mercury, selenium, and silver) were included in soil investigations of SWMUs and in the groundwater investigation.

AOI 2

As the 12-3 unit was a crude processing plant, the comprehensive COC list was used for the soil investigation. The petroleum list was shortened for groundwater to include only Evergreen Petroleum Short List parameters as the additional parameters on the Evergreen Comprehensive List were not detected above the applicable standards in soil. Additional RCRA metals (arsenic, barium, cadmium, chromium, mercury, selenium, and silver) were included in soil investigations of SWMUs and in the groundwater investigation.

AOI 3

As the 8C unit was a crude processing plant and many of the historical storage tanks in the AOI contained slop oil, the comprehensive COC list was used for the soil and groundwater investigations. Mercury was also investigated in soil and groundwater in the vicinity of the historical mercury release. Soil samples were analyzed for polychlorinated biphenyls (PCBs) in the vicinity of AOC F, a former transformer area.

AOI 4

In AOI 4, either the Evergreen Petroleum Short List or comprehensive COC list was selected for each well or soil boring based on historical product stored in the investigation area. As some of the soil investigation activities were conducted in early 2013, prior to the establishment of the use of the comprehensive COC list at the site, these additional analytes were not initially requested for analysis. For these samples collected prior to August 2013, the laboratory was contacted regarding retrieval of additional analytes. The laboratory was not able to reanalyze for the acid extractable semivolatiles, since the holding time for the samples had expired. However, the laboratory was able to retrieve the base neutral semivolatiles, volatiles, and metals analytical runs for most of these samples. Groundwater samples collected in 2013 were analyzed for the Evergreen Petroleum Short List parameters.

1.5 SELECTION OF APPLICABLE STANDARDS AND SCREENING LEVELS

The media of concern for AOIs 1 through 4 include groundwater and soil. The potential vapor intrusion into indoor air exposure pathway was also evaluated. The approach for attaining Act 2 remediation standards for each media of concern is described in the following subsection. As the current and anticipated future use of the facility is industrial, standards for non-residential properties were chosen for comparison.

1.5.1 Groundwater

Groundwater sample results were screened against the PADEP medium specific concentrations (MSCs) for non-residential properties overlying used aquifers with total dissolved solids (TDS) less than or equal

to 2,500 milligrams per liter (mg/L), the SHS. Where constituent concentrations are above the SHS, Evergreen has evaluated application of the site-specific remediation standard using the pathway elimination option.

1.5.2 Soil

All soil results were screened using a multi-step process as described in this section. Soil sample analytical results were first screened against the PADEP non-residential, used aquifer (TDS less than or equal to 2,500 mg/L) SHS. The following process was used to select the soil SHS for each COC:

- The highest value of either 100 times the groundwater MSC or the generic value MSC was selected to represent the soil to groundwater numeric value.
- The selected used aquifer, non-residential soil to groundwater numeric value was then compared to the non-residential direct contact MSC (0-2 or 2-15 feet below ground surface [ft bgs], as applicable).
- The more stringent of the soil to groundwater numeric value and the direct contact value was selected as the SHS for initial comparison of soil sample results.

The SHS value is usually driven by the soil-to-groundwater MSC, and the soil-to-groundwater pathway will be addressed in the groundwater investigation presented in this RIR (**Section 4**) and through subsequent remedial measures which will be further described in future Act 2 deliverables. In order to further evaluate the risk posed by the concentrations of COCs which were detected above their respective SHS, the next step in the screening process is to compare all of the soil analytical results to the non-residential direct contact MSCs. Soil sample locations that will require further pathway evaluation or require a remedial measure in order to attain a standard under Act 2 were identified through comparison to the non-residential direct contact MSCs.

An exception to this soil screening process exists for lead. On February 24, 2015, Evergreen submitted a Human Health Risk Assessment (HHRA) Report (Langan, 2015) to PADEP which presented the development of a risk-based numeric site specific standard (SSS) for lead in soil. In a letter dated May 6, 2015, PADEP approved the HHRA, and a non-residential direct contact site-specific numerical standard for lead of 2,240 milligrams per kilogram (mg/kg) was established. This SSS is used in place of the default 0-2 ft bgs non-residential direct contact MSC for lead and will be referred to as the lead SSS.

1.5.3 Potential Vapor Intrusion

Several types of air samples were collected as part of the remedial investigation conducted in AOIs 1 through 4 including indoor air, ambient outdoor air, and within Verizon and PECO owned utility vaults along Post Road. As it is Evergreen's intention to demonstrate that vapor intrusion is the only potentially

complete exposure pathway at the site, EPA Region 3 Regional Screening Levels (RSLs) for Industrial Air Target Risk (TR)=1E-5, Target Hazard Quotient (THQ)=0.1 (updated May 2016; EPA-RSL, TR=1E-5) are used as the threshold values to determine if additional controls will be necessary to address vapor intrusion, and any such controls will be presented in the Cleanup Plan. The EPA RSLs with TR=1E-6 and THQ=0.1 (EPA-RSL, TR=1E-6), the non-residential PADEP Indoor Air Site Specific Standard Vapor Intrusion Screening Values (SVIA-NR SHS; PADEP, effective 2017), the non-residential PADEP Indoor Air Statewide Health Standard Vapor Intrusion Screening (SVIA-NR SSS), the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs); the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs) and the American Conference of Governmental Industrial Hygenists (ACGIH) Threshold Limit Values (TLVs) are also provided for reference.

2.0 ENVIRONMENTAL SETTING

2.1 TOPOGRAPHY AND STORM WATER

Light Detection and Ranging (LiDAR) data obtained from the United States Geological Survey ([USGS], 2010) indicates that present-day topography is relatively flat across the facility, rising gently to the north from approximately 6 feet along the bank of the Delaware River to approximately 60 feet along Ridge Road [referenced to the North American Vertical Datum of 1988 (NAVD 88)] (**Figure 2-1**). Just north of the facility, steeper topography is apparent. Storm water sheet flow follows topography and generally flows south across the property towards the Delaware River. The facility's combined wastewater/stormwater drainage system collects process wastewater and stormwater from all process areas of the facility except for the east side of the facility. In this area, storm runoff is sent to an 84-inch pipe that combines with runoff from the surrounding community and discharges at National Pollutant Discharge Elimination System (NPDES) permitted Outfall 020. All storm lines, except those draining to Outfall 020, drain first to Impoundment Tank T-101-K, then to the separator/wastewater pretreatment plant, and then finally to the Delaware County Regional Water Quality Control Authority (DELCORA) Publicly Owned Treatment Works (POTW).

The Ethylene Complex, located in the southwest corner of the facility in Claymont, Delaware, has a segregated sewer system. One system collects process wastewater and process area stormwater, and a second system collects other non-process area "clean" stormwater. Non-process area stormwater is discharged, via several outfalls, directly to Middle Creek and the Delaware River and is regulated under a Delaware NPDES Permit, No. DE0050288. Ethylene Complex process wastewater and process related stormwater is routed to the facility's surge tanks TK-130 and TK-131, where it receives treatment similar to that provided for other facility waste streams.

2.2 LOCAL GEOLOGY

The facility is located on the up-dip edge of the Coastal Plain Physiographic Province near its contact with the Piedmont Physiographic Province. The Coastal Plain is characterized by relatively flat topography and is underlain by unconsolidated deposits of mud, sand, and gravel-sized materials. This is in contrast to the Piedmont Province, which is characterized by steeper topography and is underlain by crystalline bedrock of the Appalachian foothills (including residual soils and a surficial weathered bedrock zone of variable thickness). Within the Coastal Plain, sedimentary deposits generally decrease in thickness and "pinch out" against crystalline bedrock of the Piedmont along a transition zone referred to as the "Fall Line," which is generally located along the northern boundary of the facility (**Figure 2-1**). The regional-scale geologic mapping displayed on **Figure 2-1** for Pennsylvania includes inferred exposures of bedrock along incised stream valleys which may or may not be representative of actual conditions at the facility. The Coastal Plain consists of a seaward-thickening, wedge-shaped sequence of sedimentary deposits that accumulated in a variety of marine and non-marine environments. Defined geologic units/formations of the Coastal Plain outcrop and subcrop the facility and generally strike northeast/southwest, dip to the southeast, and overlie a deepening bedrock surface.

According to published geologic maps of the facility area, sedimentary deposits of the Coastal Plain near the facility may range in age from Cretaceous to Holocene (**Figure 2-2**). In Pennsylvania, the Coastal Plain sediments are mapped as belonging to the Quaternary Trenton gravel, which is generally present between sea level and 40 feet above mean sea level (along a river terrace) with local thicknesses that are commonly less than 20 feet (Balmer & Davis, 1996). The Trenton gravel is discontinuous in aerial extent, variable in vertical thickness and range of elevation, and primarily consists of gravelly sand interstratified with semi-consolidated sand (limonite-cemented) and clay-silt beds (Owens and Minard, 1979). The Trenton gravel is commonly gray or reddish brown in color. In a spatial pattern that generally flanks the lowlands along the Delaware River, the Trenton gravel is in places overlain by recent alluvium and marsh deposits.

In Delaware, Quaternary deposits are mapped as undifferentiated Delaware Bay Group (upper Pleistocene) consisting primarily of sandy alluvium but with secondary lithologies including silty clay, peat, and sandy gravel in thicknesses up to 20 feet (Ramsey, 2005). Across the Delaware River in New Jersey, near time-equivalent surficial deposits are mapped in a similar pattern, including the Cape May Formation, Unit 2, overlain in places nearest the Delaware River by recent marsh and swamp deposits (New Jersey Department of Environmental Protection [NJDEP]/New Jersey Geological Survey [NJGS], 2006). The Cretaceous Potomac Formation is mapped by the NJGS to reach its up-dip limit very near the facility and as such those older deposits could subcrop Quaternary deposits in the area (NJDEP/NJGS, 1999). If present, geologic mapping data indicates that the Potomac Formation deposits would be of limited thickness and geographic extent, and would primarily be composed of very fine to coarse sand beds (with common lignite) interbedded with mud (NJDEP/NJGS, 1999; Ramsey, 2005).

According to the Bedrock Geology Map of the Piedmont of Delaware and Adjacent Pennsylvania (Schenck, Plank, and Srogi, 2000), bedrock beneath the facility is of the Wilmington Complex. The Wilmington Complex consists of metamorphosed igneous rocks including meta-volcanic units, meta-plutonic units, and un-deformed plutons. The complex is a fragment of an Ordovician-Silurian magmatic arc with later Silurian intrusions (Plank and others, 2000). The majority of the complex exists in New Castle County, Delaware. Three bedrock geologic units of the complex extend into Pennsylvania, including the Ardentown Granitic Suite of the Arden Plutonic Supersuite which is mapped to occur beneath the facility. The Silurian-age Ardentown Granitic Suite is a collection of silicic rocks that probably crystallized from a granitic magma (Srogi and Lutz, 1997). Specifically, the suite includes quartz norite, quartz monzonorite, opdalite, and charnockite. The mineralogy common to all rock types is plagioclase, orthopyroxene, clinopyroxene, potassium feldspar, quartz, and biotite.

More recently Bosbyshell (2005) published an updated bedrock geologic map that included mapping of the facility area (**Figure 2-2**). Although bedrock was not mapped beneath the Coastal Plain, that map continues to indicate that the Ardentown Granitic Suite is present beneath portions of the facility, and that just east of the facility a newly identified bedrock geologic unit, the Ordovician-age Chester Park Gneiss, may be present beneath Coastal Plain sediments.

2.2.1 Facility Geology

On the basis of available lithologic data from boring logs (**Appendix C**), the principle of stratigraphic position, review of historical consultant reports and cross-sections, and review of historical maps, the following stratigraphy has been interpreted in the subsurface beneath AOIs 1 through 4. A stratigraphic cross-section has been prepared along the profile shown in **Figure 2-3**. The profile presented as **Figure 2-4** is a generalized geologic cross-section extending from the northwestern extent of AOI 1 to the Delaware River.

Although the subsurface conditions at the facility above bedrock are locally heterogeneous, the geologic framework underlying the facility can be grouped into four general units. The uppermost unit is anthropogenic fill, which generally covers the entire surface of the facility to varying depths. Underlying the fill is recent alluvium consisting primarily of silty clay which may have been deposited in estuarine environments of the Delaware River or a tributary, such as Middle Creek. The third unit includes heterogeneous, unconsolidated sands and gravels with minor silt and clay, which fits published descriptions of the Trenton gravel (or adjacent Delaware Bay Group in Delaware). The lowermost unit appears discontinuous but where present can include a micaceous and lignitic mud layer, peat, and brown and gray fine, silty sand that appears distinct in lithology from the Trenton gravel and fits published descriptions of the Potomac Formation.

Fill has been reported to be present underlying the entire facility at variable extent and thickness ranging from approximately 1 to 25 feet. The fill composition varies, but generally is composed of one or more of the following: silt, sand, gravel, clay, wood fragments, cinders, apparent dredged material, sludge, spent clay, and other construction/demolition or refinery materials. Portions of the facility that extend beyond the historical Delaware River shoreline of 1937 were generated by filling of the river margin with various refinery-generated materials. This area generally correlates with that shown as Fill (f) on **Figure 2-2** (Ramsey, 2005).

Underlying the fill are predominantly silty clay sediments, hereafter referred to as the silty clay layer. The silty clay layer within the facility consists of micaceous, greenish-gray to dark gray silty clay with minor roots, wood, peat, and other vegetative material, but can vary to include interbedded fine-grained sands, silty sands, clayey silts, and gravels. The silty clay generally has a soft consistency but can become stiff with depth or where sandy. The lithology of the silty clay layer is consistent with what Owens and Minard (1979) describe as Delaware Bay estuarine deposits, an organic-rich estuarine facies consisting of dark colored clayey silts interbedded with fine to very fine sand. The silty clay layer is present beneath most of the facility and generally thickens towards the east and the historical shoreline of 1937. Beneath the facility, the silty clay layer ranges in thickness from approximately 5 to 20 feet.

Apparent Trenton gravel deposits underlie the silty clay layer and in places unconformably overlie bedrock at the facility. The Trenton gravel generally ranges in thickness from approximately 2 to 10 feet. The Trenton gravel consists of fine to coarse-grained sand, gravel, sandy silt, and clayey sand. The sand and gravel unit is present throughout much of the facility; however, its thickest deposits vary laterally. The sands and gravels commonly coarsen with increasing depth. Cobbles may be present at the base of the unit in some areas of the facility, generally along the shoreline of the Delaware River.

On the basis of stratigraphic position and lithology, it appears from test boring data that the Potomac Formation may be present beneath the facility in very limited thickness and aerial extent. Where observed, these deposits are generally less than 10 feet in total thickness and appear to occupy a subtle trough in the bedrock surface nearest the Delaware River. Lithologies include pinkish gray to gray clay with a stiff consistency, banded fine sands, peat, and pale brown to yellow fine to medium sand.

Bedrock at the facility has been identified through test boring advancement. Where encountered, a saprolite layer is common that contains a visible rock fabric consistent with published descriptions of Ardentown Granitic Suite crystalline bedrock. Along the northern facility boundary, bedrock was identified near surface beneath a veneer to a few feet of fill. The bedrock surface slopes south and deepens towards the Delaware River. The elevation of the top of crystalline bedrock (including saprolite) at the facility ranges from approximately 30 feet to deeper than -50 feet NAVD 88.

2.3 LOCAL HYDROGEOLOGY AND WATER BODIES

In southeastern Pennsylvania, unconsolidated sands and gravels of the Coastal Plain and fractured crystalline bedrock of the Piedmont can function as aquifers where saturated and sufficiently permeable. Crystalline bedrock, particularly igneous and high-grade metamorphic rock types such as those associated with the Wilmington Complex, generally has low porosity with little, if any, secondary porosity/permeability yielding poor water-producing capabilities. Near the facility, these rocks have been described to yield too little water for industrial or public water supply (Balmer and Davis, 1996) and have a median well yield of less than 10 gallons per minute (gpm) (Bosbyshell, 2005). Where unconsolidated Coastal Plain sediments are present at the land surface, these rock types have been further described to "serve chiefly as a lower confining layer to retard movement of water of the overlying aquifers" (Greenman and others, 1961). Balmer and Davis (1996) provide a median yield of 50 gpm for wells screened in the Trenton gravel in Delaware County. However, transmissivities may be much lower due to that deposit's limited saturated thickness and local-scale heterogeneity. In addition, recent alluvial deposits, including the Delaware River Estuarine silty clay and the Trenton gravel, are not expected to represent a significant potable water source in eastern Delaware County based on potential saline/brackish water impacts from the Delaware River (Balmer and Davis, 1996). The facility and the areas surrounding the facility are served by a public water supply and river water intakes.

2.3.1 Facility Water Bodies

Figure 2-5 shows the locations of historical streams and marshes circa 1898. In this figure, a former perennial stream, shown on later facility maps as "Walker's Run," (Brown and Root, 1993) daylights as a spring at the slope located just to the north of Ridge Road. It flowed along the western side of Hewes Avenue, beneath the Amtrak/Norfolk Southern Railway, and into AOI 4, where it meandered to the east. At that point, it curved around a topographic high whose northern extent is near the present day H-5 Control Room. Walker's Run then took a gentler turn due south, at which point it became flanked by fringing marsh area and flowed through present day AOI 2, just to the east of and then through 12 Plant Sludge Basin. Near the corner of 5nd Street and Hewes Avenue, Walker's Run turned southwest before flowing out to the Delaware River. This northeast/southwest trending portion of the surface water feature is shown on facility maps to be "Middle Creek" (Brown and Root, 1993). An additional stream is also

noted to have existed to the west of AOI 4 and merged with Middle Creek near its confluence with the Delaware River.

The course of these surface water features has been altered throughout the development of the former refinery, and, until the early 1990's, Middle Creek and Walker's Run served as channels for containment and transport of both local stormwater and process wastewater. This system, known as the Middle Creek Surface Drainage System, was designated as SWMU 95 in the 1991 Phase II RFA. This open and unlined drainage system was closed between 1993 and 1995 through the implementation of the Middle Creek Abatement Project outlined in the Closure Plan and Post-Closure Plan (Brown and Root, 1993). At that time, the majority of Middle Creek became contained in a conveyance system. Storm water now mostly travels through an open concrete channel, roughly following the former Walker's Run and Middle Creek beds, and process waste is conveyed within enclosed piping inside of the concrete channel. The stormwater conveyance terminates just east of Blueball Avenue at a sump (Brown and Root 1993), and then goes through an onsite treatment process before being transferred to the publicly owned treatment facility at the DELCORA. Currently, a remnant of Middle Creek exists to the southwest of the concrete dam located in the vicinity of the Middle Creek Interceptor Trench Recovery System (AOI 5) and connects to the Delaware River at the southwestern corner of the facility in Delaware (AOI 7). A sheet pile bulkhead exists along the facility boundary with the Delaware River.

2.3.2 Facility Hydrogeology

At the facility, monitoring well data indicate that groundwater can occur in areas of fill, the silty clay layer, Trenton gravel, and/or Potomac Formation deposits at depths ranging from approximately 1 to 20 feet bgs. Groundwater generally occurs within these strata under unconfined conditions as one continuous water-bearing unit (e.g., water-table aquifer), and groundwater elevations generally decrease towards the shoreline of the Delaware River. However, perched groundwater can occur within the fill layer where the fill is present atop the silty clay layer, and where the top of the silty clay layer is above the regional zone of saturation.

Presently, a network of approximately 550 monitoring wells and 120 recovery wells is used to monitor groundwater quality, understand pattern(s) of groundwater flow, and recover LNAPL within the facility (**Figure 1-2**). To evaluate recent, facility-wide patterns of groundwater flow, groundwater elevation contour maps were created for annual well gauging events performed in 2014 and 2015 (**Figures 2-6** and **2-7**, respectively). Based on the groundwater contours presented, the average hydraulic gradient across the facility is approximately 0.007 feet/foot (ft/ft), and site-wide groundwater flow is generally towards the southeast. However, some variability in groundwater flow direction is noted. Groundwater flow appears to be affected by Middle Creek along its exposed portion, where there is potential for groundwater discharge to surface water. Groundwater elevations are also locally depressed in areas of active groundwater recovery and remediation systems. Groundwater elevations along the tidal Delaware River appear to be influenced by semidiurnal tides, where maximum groundwater fluctuations of approximately 1 foot to 2.7 feet immediately adjacent to the river and 0.1 to 0.15 feet approximately 300 feet inland were recently observed in monitoring wells during a tidal study conducted by GHD (**Appendix D**).

Patterns of groundwater flow within the facility that deviate from the overall southeasterly flow direction are described in detail in the following section, beginning in the northern extent of the facility and extending to the south. In the northwestern area of the site between Ridge Road the Amtrak/Norfolk Southern Railroad (AOIs 1 and 4), groundwater flow is reasonably uniform to the southeast, toward the Delaware River with a gradient ranging from approximately 0.010 to 0.019 ft/ft. The exception to this is the northern portion of AOI 1, where the gradient is approximately 0.05 ft/ft as a result of the steeper topography along Ridge Road. In AOI 4, south of the railway, an anomaly is present in the subsurface which changes the consistent pattern of the gradient. Notably, there is an apparent groundwater mound present in the area of the Auto Lab Building in the southern corner of AOI 4 that may be due to the presence of a closed-in-place UST excavation backfilled with relatively permeable materials compared to surrounding soils (i.e., pea gravel). Generally, in AOI 4 between the railway and Post Road, groundwater flow is to the south and southeast, mirroring historical topography (**Figure 2-5**). In AOI 2, contours support an easterly component of groundwater flow. This location correlates to the buried stream valley of Walker's Run as shown on **Figure 2-5** and described in **Section 2.3.1.** Nearer the Delaware River and generally in AOIs 2 and 3, the hydraulic gradient flattens out to approximately 0.005 ft/ft. Some localized groundwater mounding is apparent in this area, possibly due to saturation of fill materials along the fringes of former Walkers Run, including the 12 Plant Sludge Basin, and backup of groundwater behind the river bulkhead.

3.0 SOIL INVESTIGATION METHODOLOGY AND RESULTS

The following sections summarize the soil investigation activities performed in AOI 1 through 4 between 2013 and 2016 by Stantec, Aquaterra Technologies, Inc (Aquaterra), and Langan in coordination with Evergreen. The goal of the investigation was to characterize soil in potential source areas including open storage tank incident areas, historical releases, product handling and storage locations, and RCRA SWMUs and AOCs. In addition to collecting soil samples from borings advanced for the source-targeted soil investigations, soil samples were collected during all monitoring well installation activities regardless of whether the area was expected to contain a source in soil.

All fieldwork was performed in accordance with the Quality Assurance/Quality Control Plan and Field Procedures Manual *(***Appendix E**). The general strategy for the investigation was to characterize soil in the 0-2 ft bgs and 2-15 ft bgs intervals. Subsurface soil samples were generally collected at the depth exhibiting the highest photo ionization detector (PID) reading or above the water table. Delineation was performed to the higher the non-residential direct contact MSC and the lead SSS. Soil boring locations are shown on **Figure 3-1**, **Table 3-1** summarizes the soil boring rationale, and soil boring logs are included in **Appendix C**. Soil analytical results are summarized on **Table 3-2**, which compares the results to the non-residential SHS, and **Table 3-3**, which compares the results to the higher of the non-residential direct contact MSC and the lead SSS. Soil samples were submitted to Pace Analytical Services, Inc., Accutest Laboratories, or Eurofins Lancaster Laboratories Environmental, LLC. All laboratory analytical reports from this investigation work are included in **Appendix F**.

Included in the discussions in the following sections are descriptions of soil investigations related to open storage tank incidents. Evergreen intends to address all open storage tank incidents for AOIs 1 through 4 for which it is responsible through the 25 PA Code Chapter 245 Corrective Action Process (CAP) Program (PADEP, 2002) under separate cover and in the near future. Site Characterization Reports/Remedial Action Completion Reports (SCR/RACRs) will be submitted for these incidents.

3.1 AOI 1

Soil characterization activities were performed by Aquaterra in 2014 and Stantec in 2015. The 10-4 FCCU was the main product handling area in AOI 1. As the primary purpose of this unit was to split long chain hydrocarbons into high octane compounds for gasoline and fuel oil blending, all soil samples were analyzed for the Evergreen Petroleum Short List. RCRA metals were added to the analyte list in the SWMU areas and to evaluate background metals levels in three boring locations.

3.1.1 Historical Product Handling/Storage Areas

Prior to demolition activities in the 10-4 unit area, Aquaterra collected samples from five locations ("10-4 Pre Demo_1" through "10-4 Pre Demo_5") to investigate surface soil. The samples were analyzed for the Evergreen Comprehensive List, RCRA metals, and PCBs. PCB results are shown on **Table 3-4**. Soil sample results did not exceed the higher of the non-residential direct contact MSC or the lead SSS.

Following the demolition of the 10-4 Plant process unit, Stantec oversaw the advancement of soil borings in the 10 Plant area, in an approximately 200 ft by 200 ft grid. This grid was intended to cover the 10-4 Plant unit, which was located mainly in the southern half of AOI 1, as well as other historical product storage areas (such ASTs in former 10 Plant Tankage Area) that were located to the north of the FCCU. Some of these grid nodes were biased to areas of known releases, as will be discussed in detail in **Section 3.1.3**, and additional soil borings were added between the grid nodes to further investigate RCRA SWMUs, as will be discussed in detail in **Section 3.1.2**. As previously mentioned, RCRA metals were added to the analyte list in the SWMU areas and to evaluate background levels of metals outside of SWMU areas (AOI1_BH-15-03, AOI1_BH-15-05, AOI1_BH-15-07). In total, 38 soil borings and 12 monitoring wells with associated soil samples were advanced in and around the 10 Plant area, and none of the results exceeded the higher of the non-residential direct contact MSC or the lead SSS.

3.1.2 RCRA SWMUs

Some of the borings completed as part of the 10-4 unit sampling also served to investigate RCRA SWMUs. Additional soil borings were added in between grid nodes to investigate SWMUs where appropriate. It should also be noted that soil boring locations were significantly limited by access. Former building foundations and debris from demolition activities were very common in this area. As previously mentioned, the soil samples collected in the SWMU areas were analyzed for RCRA metals in addition to the Evergreen Petroleum Short List. Soil borings AOI1_BH-15-22 through AOI1_BH-15-27 and AOI1_BH-15-34 were performed to investigate SWMUs 35-39, 41, 42. 43, and 44 which are located in close proximity to one another.

SWMUs 35–39: 10-4 Plant Catalyst Fines Collection Roll-Offs

SWMUs 35 through 39 were part of the 10-4 Plant Unit Process and included closed-top steel containers on a concrete-lined pad containing catalyst fines from the FCCU (A.T. Kearney, 1991). The catalyst fines would later be transported to the Solid Waste Facility (SWF) where they were used as a pre-coat for the sludge filter press. This unit stored wastes from 1963 until December 2011, when the refining operations and units were idled. Soil borings AOI1_BH-15-23, AOI1_BH-15-24, AOI1_BH-15-25, and AOI1_BH-15-34 were completed in the vicinity of SWMUs 35-39, and concentrations of COCs were not detected in exceedance of the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 41: 10-4 Spent Catalyst Silo

SWMU 41 was a storage silo for the FCCU spent catalyst and was in operation from 1963 until December 2011, when the refinery was idled. This unit was a closed-top silo located on a concrete-lined pad, with no historical evidence of releases at (A.T. Kearney, 1991). Soil borings AOI1_BH-15-024 and AOI1_BH-15-25 were completed in the vicinity of SWMU 41, and concentrations of COCs were not detected in exceedance of the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 42: 10-4 Plant Electrostatic Precipitator

SWMU 42 consists of air emissions control units for the FCCU spent catalyst fines and was in operation from 1963 until December 2011, when the refinery was idled. This was an enclosed unit located on a concrete pad (A.T. Kearney, 1991). Soil borings AOI1_BH-15-22, AOI1_BH-15-23, AOI1_BH-15-24, and AOI1_BH-15-25 were completed in the vicinity of SWMU 42, and concentrations of COCs were not detected in exceedance of the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 43: 10-4 Plant Sour Water Stripper

SWMU 43 was a steel packed tower stripper used to control sulfur emissions from the steam and flue gases emitted from the FCCU. The unit was located on a concrete surface in the FCCU process area and had a throughput of 200 gpm. The substances present in this unit were sour water, sulfides, and phenols. The sour water containing hydrogen sulfide (H_2S) was piped to the gas plant located to the west of the facility where the sulfur was recovered (A.T. Kearney, 1991). The sour water was drained through SWMU 95 to the 10 Oil/Water Separators (SWMUs 81, 82) and then Middle Creek (SWMU 96) (A.T. Kearney, 1991). This unit was in operation from 1964 until December 2011, when the refinery was idled. Soil boring AOI1_BH-15-24, completed in the vicinity of SWMU 43, did not exhibit exceedences of the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 44: Plant Catalyst Regeneration Unit

SWMU 44 was a Catalyst Regeneration Unit which involved the FCCU catalysts, and operated from 1963 until December 2011, when the refinery was idled. This was an enclosed unit located on a concrete-lined pad, with no historical evidence of releases (A.T. Kearney, 1991). Soil borings AOI1_BH-15-26 and AOI1_BH-15-27, completed in the vicinity of SWMU 44, did not exhibit exceedences of the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 40: 10-4 Plant Roll-Off Storage Area

One additional SWMU was located AOI 1 away from the cluster near the FCCU area. SWMU 40 is located in in the southwestern corner of the 10 Plant area.

SWMU 40 was part of the 10-4 Plant Unit Process located in the vicinity of the FCCU, and was a staging facility used for 10-4 Plant Catalyst Fines Collection Roll-Offs (SWMUs 35-39) prior to transport to the SWF. These roll-offs contained catalyst fines and spent aluminum-silica catalysts from the 10-4 Plant Spent Catalyst Silo (SWMU 41). The unit was an unpaved, outdoor area, approximately 200 ft by 50 ft, and filled with approximately twenty, 30-cubic yard, roll-off containers (A.T. Kearney, 1991). This unit was in operation from 1945 until December 2011, when the refinery was idled.

Soil borings AOI1_BH-15-19 and AOI1_BH-15-20 were performed to investigate SWMU 40, and none of the results exceeded the higher of the non-residential direct contact MSC or the lead SSS.

3.1.3 Historical Releases

In a review of internal facility files, the following releases were identified, and the releases were investigated as part of the AOI characterization activities.

10 Plant Fraid Stack

On April 4, 2000, a safety failed, releasing 800 to 1200 gallons of gas oil onto the ground in the northwest corner under the Fraid Stack. Soil boring AOI1_BH-15-11 was completed adjacent to the structure of the former Fraid Stack. COCs were not detected at concentrations exceeding the higher of the non-residential direct contact MSC or the lead SSS in the samples collected from the AOI1_BH-15-11 soil boring.

10 Plant #2 Salt Dryer

On March 8, 2006, the #2 Salt Dryer overflowed to the gravel due to a valve that was shut but was still allowing light cycle oil (LCO) to pass through. Approximately 200 gallons of LCO came out of the top vent of the vessel. The oil was cleaned up with a vacuum truck. Soil boring AOI1_BH-15-32 was completed in the area of the former #2 Salt Dryer. COCs were not detected at concentrations exceeding the higher of the non-residential direct contact MSC or the lead SSS in the samples collected from the AOI1_BH-15-32 soil boring.

10 Plant E5 Inlet Piping

On June 13, 2008, there was a raw oil charge leak to the north unit roadway of approximately 32 barrels, when the E5 thermal relief ¾-inch inlet piping union separated while the unit was on raw oil circulation. The leak was isolated, and a vacuum truck was used to clean up the spill. The exact location of the leak is unknown. Therefore, a series of borings, AOI1_BH-15-12 through AOI1_BH-15-17, was completed along the path of the line from the AOI 1 western boundary to the location of the former unit. Concentrations of COCs were not detected in exceedance of the higher of the non-residential direct contact MSC or the lead SSS in the area of this release.

3.2 AOI 2

Soil characterization activities were performed primarily by Stantec in the spring of 2015. The Evergreen Comprehensive List was used for all soil samples collected in AOI 2 due to known handling of crude oil in the former 12 Plant. Samples were also collected for acid sludge determination in SWMU 25 (12 Plant Sludge Basin), and in other locations where field observations indicated that acid sludge might be present. The results for acid sludge determination are summarized on **Table 3-5**. A total of 58 soil borings were completed in AOI 2. All of the soil samples collected in AOI 2 had concentrations of COCs below the higher the non-residential direct contact MSC or the lead SSS with the exception of four sample locations:

- AOI2_BH-15-004: vanadium at 0-2 ft bgs
- AOI2_BH-15-049: 1,2,4-Trimethylbenzene (TMB) at 2-4 ft bgs
- AOI2_BH-15-055: arsenic at 0-2 ft bgs
- MW-519: arsenic at 0-2 ft bgs

As will be described in detail in the following sections, all of these exceedances of the non-residential direct contact MSCs have been delineated.

3.2.1 Historical Product Handling/Storage Areas

The main product handling area in AOI 2 was the former 12-3 Crude unit. Demolition of the unit was completed in early 2015, and a soil sampling program was initiated prior to the conversion of the area to a contractor's parking lot. A soil boring grid of approximately 100 ft by 100 ft was performed in the area. All soil borings were visually inspected, primarily for the presence of acid sludge due to the potential for migration of this material from the 12 Plant Sludge Basin (SWMU 25) located to the southwest (further discussion of this area is in **Section 3.2.2**). Soil samples for laboratory analysis of the Evergreen Comprehensive List were submitted from alternating locations. The exception to this was along the eastern property boundary where samples were submitted for laboratory analysis from each location. A total of 35 soil borings were completed in and around the former 12 Plant area with soil samples from 20 boring locations being submitted for laboratory analysis of the Evergreen Comprehensive List of COCs.

The other area of historical product storage within the AOI is the former aboveground storage tanks located near the southern AOI boundary. In order to investigate this area, soil samples were collected during the installation of monitoring wells MW-519, MW-521, and MW-522.

All of the soil samples collected for the 12-3 Crude unit investigation had concentrations of COCs below the higher of the of non-residential direct contact MSC or the lead SSS with the exception of vanadium which was detected at a concentration of 1700 mg/kg in AOI2_BH-15-004_0-2. This exceedence is delineated to the northwest, southwest, and southeast by samples collected from soil borings AOI2_BH-15-003, AOI2_BH-15-012, and AOI2_BH-15-005, respectively. An additional soil boring, AOI2-BH-16-01 was advanced to delineate the exceedence to the northeast. A sample was collected from the 0-2 ft bgs interval and was analyzed for vanadium. The result did not exceed the non-residential direct contact standard for vanadium.

3.2.2 RCRA SWMUs

Two SWMUs are located in AOI 2. SWMU 25 is 12 Plant Sludge Basin, and SWMU 83 is the 12A Oil/Water Separator. Previous reports have indicated that SWMU 65, the 1C Oil/Water Separator, is located in AOI 2. However, this SWMU is located on the western side of the Middle Creek conveyance in AOI 5 and will be characterized during the remedial investigation for AOI 5.

SWMU 25: 12 Plant Sludge Basin

Nine wells (MW-511 through MW-519) were installed in and around SWMU 25, and nine soil borings (AOI2_BH-15-044 through AOI2_BH-15-052) were advanced near the southern end of the SWMU to delineate the presence of acid sludge in this direction. Shallow samples were not collected in areas where a temporary soil cover was placed over the area of suspected sludge. Soil samples for laboratory analysis of the Evergreen Comprehensive List and RCRA metals were collected from the soil interval below the acid sludge, above bedrock, if present. If acid sludge was not present, soil samples were collected from the interval with the highest PID readings or above the water table, as observed.

With three exceptions, concentrations of COCs did not exceed the higher of the non-residential direct contact MSC or the lead SSS in the delineation samples. As will be discussed in additional detail in the following section outlining the investigation of SWMU 83, the concentration of 1,2,4-trimethylbenezene in the 2-4 ft soil sample collected from the AOI2_BH-15-049 boring location was detected above the non-residential direct contact standard. Arsenic was detected above its non-residential direct contact standard in the sample collected from MW-519. Additional soil borings (AOI2_BH-15-053 through AOI2_BH-15-057, AOI2_BH-15-062, and AOI2_BH-15-063) were completed to delineate the exceedences. Arsenic was detected above the non-residential direct contact standard at AOI2_BH-15-055, however this exceedance was delineated by soil boring AOI2_BH-15-062.

In addition to the soils collected for laboratory analysis, samples of potential acid sludge were identified in the field based on color, cohesiveness, consistency, and 5-gas meter readings, and sent to an internal Stantec laboratory for determination of presence of acid sludge. Soils containing no field evidence of presence of sludge were not sent for further analysis. During boring advancement, a sludge sample was collected when it was first encountered. In some locations, a second sludge sample was collected if the sludge was observed to be layered and exhibiting different characteristics. Thirteen samples from the former 12 Plant area were submitted to the Stantec laboratory for determination of the presence of acid sludge. The following evaulations were performed on the samples submitted to the laboratory for acid sludge determination and to document characteristics of the samples: pH, density, sulfur dioxide odor (qualitative presence), naphthalene odor (qualitative presence), acidity (as percent calcium carbonate [$CaCO_3$]), and physical description. The results of the acid sludge evaluations are shown on **Table 3-5**. The acid sludge determinations from this investigation are shown on **Figure 3-3.** It should be noted that some of the proposed borings were not completed due to access restrictions. Within the former 12 Plant area, samples for acid sludge determination were collected from borings AOI2_BH-15-027, AOI2_BH-15-028, AOI2_BH-15-030, AOI2_BH-15-035, AOI2_BH-15-036, AOI2_BH-15-037, AOI2_BH-15-040, and AOI2_BH-15-042. None of these samples were determined to contain acid sludge (Table 3-5). The lowest pH measured within the former 12 Plant processing area was 6.89.

During the investigation within SWMU 25 and delineation efforts to the south, samples from eleven locations were sent to the internal Stantec laboratory for determination of the presence of acid sludge. Of these, nine of the locations were determined to contain acid sludge. The results of the acid sludge evaluations are shown on **Table 3-5** and the acid sludge determinations from this investigation are shown on **Figure 3-3**, along with results of historical borings completed in this area. This figure also serves as a cross-section plan map for four cross-sections further illustrated by, **Figures 3-4** through **3-7**, that depict the extent of the main acid sludge pit in the subsurface. Acid sludge was determined to be present along the axis of the known sludge pit and is also presented in a segregated location in the southern corner of the AOI. The extent of the acid sludge was delineated in all directions. It was determined to be contained within the AOI boundaries and to be absent within the area that has recently been converted into a contractor's parking lot, as discussed in **Section 3.2.1**.

SWMU 83: 12A Oil/Water Separator

SWMU 83 consists of a corrugated plate oil/water separator, located south of the 12-3 Plant, used to treat wastewater from the 12-3 Plant Unit. The system consists of two separator components and a discharge

reservoir. The units are in-ground and covered with steel plates. They measure 20 ft by 8 ft and lie approximately 10 ft bgs. The top of the unit is surrounded by gravel-covered soil. Sludge was pumped from the unit approximately once per year and was transported to the SWF. The treated wastewater was transported to the Middle Creek Drainage System (SWMU 96). Wastewater containing petroleum distillates, cooling tower blowdown, salts, chlorine, bromine, de-salter water, phenols, hydrogen sulfide, and water used for equipment cleaning are encountered in this unit (A.T. Kearney, 1991). This unit was in operation from the 1970s until December 2011 when the refinery was idled. Borings AOI2_BH-15-048, AOI2_BH-15-049, and AOI2_BH-15-050 were completed to investigate this SWMU. Soil samples were also collected from the MW-520 location. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS with the exception of 1,2,4-trimethylbenezene in the 2-4 ft sample collected from AOI2_BH-15-049. In order to delineate this exceedance and evaluate whether a direct contact hazard exists in surface soil, 0-2 ft soil samples were collected from AOI2_BH-15-049 and AOI2_BH-15-050, and an additional soil boring, AOI2_BH-15-057 was completed to the north of AOI2_BH-15-049. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS in the delineation samples.

3.2.3 Open Storage Tank Incident

Tank 009A (Incident No. 45598)

On July 1, 1995, an estimated 200 gallons of No. 6 fuel oil was discovered around the ringwall of Tank 009A. Upon discovery, personnel began removing the remaining contents of the tank. According to the Notice of Reportable Release (NORR), free product around the tank was collected and returned to the refinery's oil recovery system. There is no documentation of characterization soil sampling conducted at the time of the release. Therefore in 2015, two soils borings, AOI2_BH-15-064 and AOI2_BH-15-065, were completed at Tank 009A. Additionally, a soil sample collected from monitoring well MW-521 is in the vicinity of the former tank footprint. Soil samples were analyzed for the Evergreen Comprehensive List. COC concentrations from these samples were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

3.2.4 Historical Release

In a review of internal facility files, the following release was identified, and was subsequently investigated as part of the AOI characterization activities.

600 Line

On March 8, 2010, approximately 20 barrels of vacuum gas oil (VGO) were released from underground line 600 (600 line) during transfer from 12 Plant. VGO was recovered by vacuum truck. VGO was observed in a sump (3 Sump) located adjacent to the 600 line, just to the west of the railroad tracks. In addition, the area was excavated and a buried flange was repaired. Four soil borings, AOI2_BH-15-058 through AOI2_BH-15-061 were completed around the sump location. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

3.3 AOI 3

The soil investigation in AOI 3 was conducted primarily by Aquaterra in August and September 2014. The Evergreen Comprehensive List was used for all soil samples collected in AOI 3 due to known handling of crude oil in the former 8-C Plant Crude Unit, residual oils in the former Clay Contact Plant Area, and slop oil in the AST area in the northwest corner of AOI 3. The only exceptions were for samples collected in the mercury release area and in the former transformer area, AOC F, which are described below in **Sections 3.3.2 and 3.3.4**. A total of 90 soil borings were completed in AOI 3. All of the soil samples collected in AOI 3 had concentrations of COCs below the higher the non-residential direct contact MSC or the lead SSS with the exception of one sample location:

- AOI3_BH-14-050: vanadium at 0-2 ft bgs

3.3.1 Historical Product Handling/Storage Areas

In preparation for the submission of the CCR, a passive soil gas sampling event was conducted in 2009, to screen soils for the presence of hydrocarbons near the edges of known LNAPL plumes. The goal was to screen for source areas in soil and groundwater, and identify appropriate locations for the installation of monitoring wells with associated soil borings. The results of the passive soil gas survey are included in **Appendix G** and sample locations are shown on **Figure 3-8.** Based on these results, installation of monitoring wells MW-278 through MW-290, and associated soil sampling, were completed in 2010. None of the results for soil samples exceeded the higher of non-residential direct contact MSC or the lead SSS.

There are three primary areas of known historical product handing in AOI 3: the former AST area near the northern central portion of the AOI, the former AST area east of the former Clay Contact Plant and the former 8-C Plant Crude Unit. These areas were identified using historical site maps and aerial photos. In 2010 through 2014, soil samples were generally collected in these known historical areas of product handling in 100 ft by 100 ft grids (AOI3_BH-14-024 through AOI3_BH-14-033, MW-283, MW-279, MW-493, MW-494). None of the results exceeded the higher of the non-residential direct contact MSC or the lead SSS.

ASTs 29 through 33 were formerly located along the northwestern boundary of AOI 3, and were commonly referred to as the A Pump House tanks. The tanks were drained, cleaned, ventilated, and plugged sometime in December 2001 through January 2002 and according to PADEP, were listed as permanently closed-in-place July 16, 2004. These tanks historically contained only lube oil and were associated with the Lube Service Center, which was located in AOI 6. The tanks were removed from February 10 through February 20, 2014. PADEP indicated in correspondence on August 1, 2014 that sampling beneath the tank pads would be sufficient to complete the closure assessments. On August 18 and 19, 2014, soil borings AOI3_BH-14-019 through AOI3_BH-14-023 were installed in the approximate center point of each tank footprint and soil samples were collected. None of the results exceeded the higher of the non-residential direct contact MSC or the lead SSS.

3.3.2 RCRA SWMUs/AOCs

The following RCRA SWMUs and AOCs were investigated in AOI 3.

SWMU 52: Lab Waste Accumulation Building

This is an active satellite accumulation area for the current operations. It is listed in the RFA as a SWMU with little or no potential for release as it is an indoor unit with waste stored in cabinets in a building with a concrete floor. Therefore no soil sampling was warranted or performed. A visual inspection was conducted by Stantec in February of 2016 and neither visual evidence of impacts nor storage of waste materials was observed.

SWMU 53: 8-C Plant Drip Showers

This outdoor unit consisted of four grated sumps that were used to clean residual oil from parts, machinery, and equipment, and was located inside of a concrete process area (A.T. Kearney, 1991). The precise location of this feature is not known; therefore, the integrity of the unit cannot be inspected as suggested in the RFA. The area currently consists of a gravel lot used for parking and equipment staging. A 50 ft by 50 ft grid of soil borings (AOI3_BH-14-034 through AOI3_BH-14-041 and MW-499) was advanced to the water table in the area, in order to characterize soils for SWMU 53. In addition to the Evergreen Comprehensive List, some samples were also analyzed for PCBs as will be discussed later in this section. No concentrations of COCs were detected above the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 57: Clay Contact Plant Area

The former Clay Contact Plant was part of a naphthenic lubricating and specialty oils production process that operated from the 1940s to 1983 (A.T. Kearney, 1991). In this plant, a multi-stage process utilized filter clays to remove contaminants from the oils. Information regarding the construction of the plant is not available, and the area is currently a gravel parking lot. A 50 ft x 50 ft grid of soil borings (AOI3_BH-14-042 through AOI3_BH-14-058) was advanced to the water table in the area in order to characterize soils for SWMU 57. Soil samples from existing well locations, MW-280 and MW-281, are located in the area, and MW-281 was used as a grid node. Soil boring AOI3_BH-14-063 was also performed just to the southwest of SWMU 57 in response to a the 2009 LNAPL delineation driven passive soil gas survey. No concentrations of COCs were detected above the higher of the non-residential direct contact MSC or the lead SSS with the exception of vanadium in sample AOI3_BH-050_0-2. This sample was collected at the central western edge of SWMU 57. The exceedance is delineated to the northwest, northeast, and southeast by samples collected from soil borings AOI3_BH-14-047, AOI3_BH-14-051, and AOI3_BH-14-053, respectively. An additional soil boring, AOI3-BH-16-01 was advanced to delineate the exceedence to the southwest. A sample was collected from the 0-2 ft bgs interval and was analyzed for vanadium. The result did not exceed the non-residential direct contact standard for vanadium.

SWMU 58: Slop Oil Tank V-29

This SWMU consists of a fully-enclosed steel tank, placed on a concrete-lined secondary containment, which has been used for storage and transfer of slop oil since the 1980s and is currently in use by SPMT as PADEP tank identification number 949A. The tank has been listed in the RFA as a SWMU with low or no potential for release. Soils in the vicinity of the tank were investigated by soil borings AOI3_BH-14-017 and AOI3_BH-14-018. No concentrations of COCs were detected above the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 59: Slop Oil Tank 132

Tank 132 is a 630,000 gallon AST constructed on a concrete pad. The tank has been in use for slop oil storage since December 1, 1969. The tank is currently in use by SPMT as PADEP tank identification number 132A. The tank has an earthen containment structure. As will be described in **Section 3.3.3**, there are several releases associated with this AST, and soils in the vicinity of the tank were investigated as part of the 50 ft by 50 ft soil boring grid performed in the northwestern corner of the AOI. No concentrations of COCs were detected above the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 61: Ballast Water Tank W-12

This unit received ballast water that was pumped from docked tanker ships and was listed as a SWMU because ballast water typically contains oils and residues. The tank has since been decommissioned and demolished, but the tank pad remains. Soil in the vicinity of the tank was investigated by soil borings AOI3_BH-14-059 through AOI3_BH-14-062, as well as by delineation borings AOI3_BH-15-01 through AOI3_BH-15-03. No concentrations of COCs were detected above the higher of the non-residential direct contact MSC or the lead SSS.

AOC F: 8-C PCB Transformer Area

This AOC consists of a former transformer at which staining was noted in the RFA (A.T. Kearney, 1991). This transformer was located in the 8 Plant Crude Unit area, and the labeling on the transformer noted that it contained PCBs. The staining was observed under the transformer and along a small trench leading from the area to a grated sewer drain (A.T. Kearney, 1991). The transformer has since been removed. The exact location of the transformer is unclear; however, the RFA indicates that the transformer was located southeast of the crude unit, in the general vicinity of the SWMU 53 drip showers. For investigation of this AOC, Evergreen conducted systematic grid sampling in conjunction with the SWMU 53 sampling grid. As previously described, this is a 50 ft by 50 ft grid of soil borings (AOI3_BH-14-034 through AOI3_BH-14-041). The samples were analyzed for PCBs (arochlors method) in addition to the other COCs, and the results are summarized on **Table 3-4**. No concentrations of COCs were detected above the higher the non-residential direct contact MSC or the lead SSS.

3.3.3 Open Tank Incidents

Tanks 132, 137, and 139 Area

There are several known releases associated with these slop oil tanks located in the northwest corner of AOI 3. These incidents are summarized on **Table 3-6**. A soil boring grid of approximately 50 ft by 50 ft was performed in the area to address these releases and possible impacts from historical product storage. One of the incidents, PADEP number 43283, involved a release of water being decanted from Tank 132, resulting in flooding of this area. The grid strategy provided areal coverage in order to address impacts from this release. The remainder of the incidents (PADEP incident numbers 45599, 45600, 1819, 1827, 45601, 45603, and 1837) were caused by overfills and overflows. The intention was to bias samples in this area to be under tank vents or in areas of stained soil. However, tank vents were located all around the top of the tanks and not in discrete locations and surface soil staining was not observed. Therefore, the grid samples were collected around tanks as planned. Eighteen soil borings, AOI3_BH-14-001 through AOI3_BH-14-018 (**Figure 3-2**) were advanced to groundwater and soil samples were analyzed for the Evergreen Comprehensive List. None of the results exceeded the higher of the non-residential direct contact MSC or the lead SSS.

3.3.4 Historical Release

Mercury Release Area

According to the *Mercury Release Assessment* prepared by Handex in March 2001 and the draft *Site Characterization Report* prepared by GES in February 2002 (**Appendix B**), a mercury release occurred from a sewer line in November 2000. During the excavation of a 30-inch brick sewer line, out-of-service cross lines were required to be cut and removed. One of these lines was reportedly an 8-inch diameter steel line (8-inch Refinery Lab sewer) which contained mercury, and a release occurred from the line to the surrounding soils. An excavation was performed in the area of the release, and, subsequently, multiple soil sampling events were conducted. Mercury was visually identified in several soil borings (AOI3_SB-7, AOI3_SB-10, AOI3_SB-11, AOI3_SB-13 and AOI3_SB-14) at depths ranging from 5 -14 ft bgs.

Passive Soil Gas Survey/Surface Soil Investigation

Due to few remaining reference landmarks in the area, locations of the historical soil borings were estimated based on sewer cleanouts visible on previous plans that are still present onsite. In order to plan a targeted soil investigation, the general area of the mercury release was screened for mercury vapors using Beacon Environmental Services, Inc. (Beacon) BeSure™ passive soil gas (PSG) collection kits. Background information including previous soil sample locations, depths, and mercury concentrations were provided to Beacon, and a sample grid of approximately 40 ft by 40 ft was recommended. Details regarding the Beacon BeSure™ PSG sampler design and construction are available in the summary report by Beacon included as **Appendix G**.

On September 23, 2014, a total of 20 PSG samplers were deployed in borings AOI3_BH-14-064 through AOI3_BH-14-083 (**Figure 3-9**). The PSG samplers were installed in 1-inch diameter temporary PVC casing. A backhoe was used to break through the upper foot of packed gravel and expose the underlying soils. A hand auger was used to advance the hole to a total depth of 3 ft bgs. A 1-inch temporary PVC

casing was then installed in the hole. The lower 18 inches of the PVC section were slotted to allow soil vapors to enter from the bottom and sides. After placing a temporary cap on the casing, the lower 18 inches of annular space was filled with clean sand and then with hydrated bentonite to 1 ft bgs. The remaining annular space was then backfilled to grade. The cap on the casing was removed and the sampler was lowered inside of the casing to the top of the slotted section using sturdy string. The cap was placed back on the casing, and the string was tied to the outside of the pipe. The samplers were retrieved about 2 weeks after deployment, on October 6, 2014. The samplers were shipped to Beacon, who subsequently sent them to EMSL Analytical, Inc., to be analyzed for mercury by NIOSH method 6009. In addition to collecting PSG samples from the AOI3_BH-14-064 through AOI3_BH-14-083 borings, soil samples were collected from the 0-2 ft bgs interval from these locations and were analyzed for mercury. Soils were also field screened for mercury vapors using a mercury vapor analyzer, and these results are displayed on the soil boring logs (**Appendix C**).

The summary report from Beacon is available as **Appendix G**. As shown on Figure 2 of the Beacon report, mercury detections were observed in the western portion of the study area, with the highest concentration of mercury vapors being detected at AOI3_BH-14-074. Concentrations of mercury in soils were below the the non-residential direct contact standards, with the highest concentration of mercury at 99.6 mg/kg.

Targeted Subsurface Soil Investigation

As mercury is a dense liquid at ambient temperature, additional soil characterization work was performed to investigate whether a direct contact hazard and/or free mercury existed in subsurface soil. Four soil borings (AOI3_BH-14-084, AOI3_BH-14-085, MW-492, and MW-503), two of which were converted to monitoring wells, were advanced to bedrock in the vicinity of what is presumed to be the source area. An additional subsurface soil boring (AOI3_BH-14-086), was completed on the western side of the release area but could not be advanced to bedrock due to access limitations. Locations were selected using a combination of the passive soil gas data, the field mercury vapor analyzer readings, previous investigation results, and to provide general coverage of the area. During soil boring advancement, free mercury was not observed. Soil samples for laboratory analysis of mercury (in additional to the Evergreen Comprehensive List) were collected from several intervals in each of these soil borings. At a minimum, samples were collected from the 0-2 ft bgs interval and the interval exhibiting the highest response on the mercury vapor analyzer. Mercury was not detected at a concentration above the non-residential direct contact standard in any of the soil samples collected.

3.4 AOI 4

The soil investigation in AOI 4 was conducted primarily by Aquaterra and Langan in the first half of 2013 and by Aquaterra in March and April 2015. As described in **Section 1.4**, either the Evergreen Petroleum Short List or Evergreen Comprehensive List was selected for each soil boring based on historical product stored in the investigation area. As some of the soil investigation activities were conducted in early 2013, prior to the establishment of the use of the Evergreen Comprehensive List at the site, these additional analytes were not initially requested for analysis. For these samples collected prior to August 2013, the laboratory was contacted regarding retrieval of additional analytes. The laboratory was not able to reanalyze for the acid extractable semi-volatiles since the holding time for the samples had expired.

However, the laboratory was able to retrieve most of the analytical runs for base neutral semi-volatiles, volatiles, and metals for these samples. A total of 70 soil borings were completed in AOI 4. All of the soil samples collected in AOI 4 had concentrations of COCs below the higher of the non-residential direct contact MSC or the lead SSS with the exception of seven samples collected from six sample locations:

- MW-411: 1,2,4-TMB 0-2 ft bgs
- MW-423: 1,2,4-TMB 0-2 and 2-4 ft bgs
- MW-388: vanadium at 0-2 ft bgs
- MW-397: vanadium at 0-2 ft bgs
- AOI4-BH-16-09: vanadium at 0-2 ft bgs
- AOI4-BH-16-10: vanadium at 0-2 ft bgs

3.4.1 Historical Product Handling/Storage Areas

In 2013, 11 soil borings and 52 wells with associated soil borings were advanced across AOI 4. Note that MW-384 was proposed as a monitoring well, but was only completed as a soil boring. The wells were generally installed in every accessible tank berm to investigate potential impacts from historical product storage. During these investigation activities, results at four locations exceeded the higher of the non-residential direct contact MSC or the lead SSS.

- 1,2,4-TMB was detected in exceedance of the non-residential direct contact MSC at boring MW-411 in the sample collected from 0-1 ft bgs. In 2015, two soil borings, AOI4_BH-15-28 and AOI4_BH-15-29 were completed to delineate this exceedance. 1,2,4-TMB was not detected above the non-residential direct contact MSC in either delineation location.
- 1,2,4-TMB was detected in exceedance of the non-residential direct contact MSC at boring MW-423 in samples collected from 0-2 ft bgs and 4-4.5 ft bgs. In 2015, three soil borings, AOI4_BH-15-30, AOI4_BH-15-31, and AOI4_BH-15-32, were completed to delineate the exceedance in the shallow soil sample. 1,2,4-TMB was not detected above the non-residential direct contact MSC in any of these delineation locations.
- Vanadium was detected in exceedance of the non-residential direct contact MSC at boring MW-388 in the sample collected from 0-2 ft bgs. In 2016, soil borings AOI4-BH-16-05, AOI4-BH-16-06, and AOI4-BH-16-07 were completed to delineate the exceedance in the shallow soil sample. Vanadium was not detected above the non-residential direct contact MSC in any of these delineation locations.
- Vanadium was detected in exceedance of the non-residential direct contact MSC at boring MW-397 in the sample collected from 0-2 ft bgs. In 2016, soil borings AOI4-BH-16-08, AOI4-BH-16-09, and AOI4-BH-16-10 were completed to delineate the exceedance in the shallow soil sample. Vanadium was detected above the non-residential direct contact MSC in two of the three borings: AOI4-BH-16-09 and AOI4-BH-16-10. These exceedances are delineated to the southeast by AOI4_BH-15-46. An additional soil boring, AOI4-BH-16-11, was completed to delineate to the southwest. Vanadium was not detected above the non-residential direct contact MSC in the sample collected from AOI4-BH-16-11. Delineation of the vanadium exceedance at MW-397 is complete.

None of the other results exceeded the higher of the SHS, the non-residential direct contact MSC, or the lead SSS.

3.4.1.1 Tanks 234 and 242

In 2015, additional soil investigation was performed in the berms for Tanks 234 and 242 in order to investigate elevated concentrations of dissolved COCs in monitoring wells MW-420 and MW-423, respectively. Three additional soil borings were completed around each storage tank (AOI4_BH-15-33 through AOI4_BH-15-35, and AOI4_BH-15-36 through AOI4_BH-15-38, respectively). COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS in the soil borings around Tanks 234 and 242.

3.4.2 RCRA SWMUs

The following RCRA SWMUs were investigated in AOI 4.

SWMU 63: 1A Oil/Water Separator

This SWMU is an oil/water separator unit, located north of the Amtrak/Norfolk Southern Railway, in the north-central portion of AOI 4. The separator was constructed in 1945 and consists of an in-ground concrete basin that is 90 ft by 20 ft in size and approximately 20 feet deep. This unit separated oil and solids from wastewater generated in the northern tank farm. The separated oil was piped to the slop oil system (Tanks V-29, 132 and 388 also identified as SWMUs 58, 59, and 60, respectively) and the solids which were removed once every 14 months were taken to the SWF (SWMUs 1– 21). The treated wastewater was piped southward under the rail line to the Combined Process/Storm Sewer System and then to the Middle Creek Surface Drainage System (SWMU 96) (A.T. Kearney, 1991). The separator was decommissioned as part of the Middle Creek closure project carried out in the mid-1990s and is currently filled to grade and capped.

Soil boring AOI4_BH-13-04 was installed to investigate SWMU 63. Concentrations of COCs at this boring were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

SWMU 81 and 82: 10A and 10B Oil/Water Separators

These SWMUs are oil/water separator units, constructed 1950, and located to the south of the 10-4 Plant in the southeastern area of AOI 4. Together, they form an in-ground basin of 100 ft by 35 ft with a depth of approximately 20 ft. These parallel units were used to separate oil and solids from wastewater generated in the 10 Plant area. The separated oil was piped to the slop oil system (Tanks V-29, 132 and 388 also identified as SWMUs 58, 59, and 60, respectively) and the solids that settled out were removed once every 6 months. The treated wastewater was discharged directly to the Middle Creek Surface Drainage System (SWMU 96). The units are surrounded by gravel on all sides and steel plates were added as cover around 1980 to minimize air releases (A.T. Kearney, 1991). The separators were decommissioned as part of the Middle Creek closure project carried out in the mid-1990s and are currently filled to grade and capped.

Soil borings AOI4_BH-13-10, AOI 4_BH-15-39, and AOI 4_BH-15-40 were completed to investigate these SWMUs. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

3.4.3 Storage Tank Incidents

3.4.3.1 Open Storage Tank Incidents

Tank 101 (PADEP Tank No. 102A, PADEP Incident No. 1833)

On May 3, 2000, a tank operator discovered that the water draw valve for Tank 101 was open. The sewer backed up, causing approximately 100 gallons of Cam II racing fuel to go into the fire dike area. The free product and contaminated soil were immediately cleaned up; however, there is no documentation of soil sampling at the time of this incident. Therefore, soil borings AOI4_BH-15-26 and AOI4_BH-15-27 were completed to characterize soils in the release area. Two samples were collected from each soil boring and analyzed for the Evergreen Petroleum Short List. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

Tank 202 (PADEP Incident No. 43286)

On September 3, 1994, a water draw valve was discovered discharging at Tank 202. After the water had been drained, gas oil began started to drain from tank into the dike area. Since the dike area drain valves are typically left closed during dry weather, the dike area became flooded with water and gas oil. Upon discovery of the release, the water draw valve was secured and the release was stopped. Soil borings AOI4_BH-15-1, AOI 4_BH-15-2, and AOI 4_BH-15-49 were completed to characterize soils in the area. Samples from these borings were analyzed for the Evergreen Comprehensive list. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

141 Line at Tank 206 (PADEP Incident No. 34811)

On February 28, 2005, approximately 150 gallons of gas oil leaked from the 141 line. The leak was repaired and contaminated soil was removed; in 2015, Aquaterra completed three soil borings (AOI4_BH-15-46 to AOI4_BH-15-48) along the 141 line on the eastern side of the tank, and had the soil samples collected from these borings analyzed for the Evergreen Comprehensive list. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

Tank 245: (PADEP Incident No. 1822)

A release of approximately 163,000 gallons of jet fuel around the base of Tank 245 was reported to have occurred on December 16, 1997. Upon discovery of the release, the tank was immediately emptied and prepared for an internal inspection. Free product was contained in the tank's dike area and subsequently removed via vacuum truck to the refinery's wastewater sewer system and treatment facilities. An internal inspection revealed a hole in the floor of the tank. All repairs were to be made before putting the tank back in service. There is no evidence of sampling conducted to characterize the release at the time of the incident.

As part of AOI 4 RI activities, Aquaterra completed four soil borings along the perimeter of Tank 245 (AOI4_BH-15-18 to AOI4_BH-15-21) and analyzed shallow and deep samples from each boring for the Evergreen Comprehensive List. In 2013, soil boring AOI4_BH-13-05 was also advanced within the

containment of Tank 245 and analyzed for the Evergreen Petroleum Short List. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

Tank 512: (PADEP Incident No. 29572)

A NoRR was filed for a release of approximately 175 gallons of a Multifunctional Additive (MFA) on September 21, 2002. The release to the containment area was found to be due to a leak under the insulation. The NoRR indicated that the material was recovered and contaminated soil removal was initiated. On October 17, 2002, Sunoco Inc. followed up with a letter to PADEP stating that all material had been recovered and disposed of properly. However, there was no soil sampling conducted following the remedial action.

Therefore, in 2015, Aquaterra completed three soil borings (AOI4_BH-15-22, AOI4_BH-15-23, and AOI4_BH-15-25) in the vicinity of Tank 512 in order to characterize this release. Shallow and deep samples were collected from each boring and analyzed for the Evergreen Petroleum Short list. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

Tank 598: (PADEP Incident No. 34683)

According to the NoRR, this incident occurred on February 2, 2005, and consisted of approximately 125 gallons of gas oil leaking from a line into the firebank of Tank 598. The leak was repaired, the released gas oil was recovered, and contaminated soils were excavated. Soil sampling was not completed at the time to characterize the release.

As part of the AOI 4 RI activities in 2015, Aquaterra completed three soil borings (AOI4_BH-15-10 through AOI4_BH-15-12) in order to characterize the leak along the line, located east of Tank 598. Samples were analyzed for the Evergreen Petroleum Short List of constituents. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

3.4.3.2 Closed Storage Tank Incident

As part of the RI work, a soil investigation was performed at UST 005 in response to PADEP Incident No. 31053. During UST system testing completed in April 2003 by Crompco Corporation (Crompco), water was detected in UST 005. Subsequently, PADEP was notified of a potential release. Further investigation of the UST system by Crompco indicated that the UST, the lines, and leak detectors passed the compliance tests at UST 005. As the release was not confirmed through these tests, no additional characterization sampling was conducted at the time of the incident. In November 2010, UST 005, along with other USTs in the Auto Lab UST system, tank field were closed-in-place.

Aquaterra completed the AOI 4 RI activities in 2015, and in conjunction, advanced eight borings (AOI4_BH-14 through AOI4_BH-14-17, and AOI4_BH-15-42 through AOI4_BH-15-45) to characterize soils associated with UST 005. Samples were analyzed for the Evergreen Petroleum Short list. Concentrations of COCs were not detected above the the non-residential direct contact MSC or the lead SSS. The incident was later closed as the release was not confirmed.

3.4.4 Historical Releases

In a review of internal facility files, the following releases were identified, and the releases were investigated as part of the AOI 4 characterization activities.

Tank 200 Area

Several releases occurred within the Tank 200 containment area.

- On April 12, 1999, an underground line leak occurred on the 53 Line which was transferring a mixture of off-test jet fuel and LCO from Tank 204 to Tank 202. The location of the line failure was in the southeast corner of the containment area surrounding Tank 200. The product flowed to the surface and was contained within the 200 tank dike area. The oil was recovered and reprocessed through the refinery. The reported quantity of the release was approximately 100 barrels.

- On February 28, 2001, a leak was discovered at a valve on the 76 Line manifold. The 76 Line manifold was isolated and the release was stopped. The quantity of the release was not known.

- On June 5, 2007, the area in and around the old K-2 pump in the 200 Tank area was found to be saturated with oil due to a suspected line leak. The quantity of the release was not known.

In order to investigate these incidents, four soil borings (AOI4-BH-16-001 through AOI4-BH-16-004) were performed within the Tank 200 containment area. Soil boring AOI4-BH-16-004 was completed in the southeast corner of the tank containment area to target the underground line leak. A surface and subsurface soil sample were collected from this boring. The description of this incident implied that the release likely covered a large area within the tank berm; therefore, three additional surface soil samples were performed to characterize surface soil. These samples were analyzed for the Evergreen Comprehensive List, and concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

Tank 201 Area

During closure activities for Tank 201, staining was noted in the swale adjacent to the tank that was not attributed to the tank system. Two soil borings, AOI4_BH-15-6 and AOI4_BH-15-50, were advanced to investigate staining in the area. The staining was determined to be a result of backups of oil/water from the storm sewer system, particularly from a sump located in the northeast corner of the tank containment area. On November 3, 2015, under Stantec oversight, soil was removed using a vacuum truck from an area approximately 15 ft by 20 ft to a depth of approximately 1 ft bgs. The visibly impacted soils located around the sump were targeted for removal. Approximately 7.5 cubic yards of impacted soil were containerized in a 15-cubic yard roll-of container along with soil excavated from the Tank 10 area in AOI 5. The disposal documentation is included in **Appendix H**. The excavated area was screened with a PID, and four post-excavation samples (AOI4-PE-15-01 through AOI4-PE-15-04) were collected from areas exhibiting the highest PID responses (3 to 45 parts per million by volume [ppm_v]). These samples were analyzed for the Evergreen Comprehensive List, and concentrations of COCs were not detected above the

higher of the non-residential direct contact MSC or the lead SSS. The extent of the excavation and post-excavation soil sample locations are shown on **Figure 3-10**.

Tank 243 Area

On January 20, 2003, a release of approximately 400 gallons of naphtha was reported from the 380A Line north of Tank 234. Upon further investigation, it was determined that the 380A Line does not run north of Tank 234, but it is north of Tank 243. Therefore, it was concluded that this incident likely occurred north of Tank 243, outside of the containment area. In 2015, three soil borings (AOI4_BH-15-3 through AOI4_BH-15-5) were completed along the 380A line. Surface and subsurface samples were collected from each soil boring and were analyzed for the Evergreen Comprehensive List. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

H-7 North of the Clay Treater

A leak was discovered on November 9, 2009 in the H-7 area. An excavation was conducted and determined that the underground leak was coming from the cat gas line to Tank 246, north of the clay treater. Product was recovered from the excavation using a vacuum truck. The quantity of the release was known. Monitoring well MW-415 was installed in the location of the release. Surface and subsurface soil samples were collected during well installation. Concentrations of COCs were not detected above the higher of the non-residential direct contact MSC or the lead SSS.

4.0 GROUNDWATER INVESTIGATION METHODOLOGY AND RESULTS

4.1 HISTORICAL GROUNDWATER INVESTIGATIONS

The oldest available well logs for AOIs 1 through 4 indicate the installation of monitoring wells occurred as early as 1984, with some existing wells likely being older. Available well construction details are summarized on **Table 4-1,** and available logs are provided in **Appendix C**. Previous consulting reports describe and present results from various historical groundwater sampling events that have been conducted. Available analytical data for wells located in AOI 1 through AOI 4, which includes results dating back to 1995, are presented in **Table 4-2**. Major historical groundwater sampling events summarized on these tables include a site-wide sampling event performed by Aquaterra in July 2011, quarterly RCRA compliance groundwater sampling performed by multiple consultants from 1995 to 2016, and annual perimeter groundwater sampling events performed by Stantec. Historically, concentrations of all COCs on the Evergreen Petroleum Short List have been detected above the SHS in unconfined aquifer groundwater, with the exception of cumene.

4.2 WELL INSTALLATION

The following section summarizes well installation activities performed in AOIs 1 through 4 between early 2013 and the end of 2015 by Stantec, Aquaterra, and Langan in coordination with Evergreen. Well installations were completed by Parratt-Wolffe, Inc of Syracuse, New York; Total Quality Drilling, LLC of Mullica Hill, New Jersey; and Lewis Environmental Group of Royersford, Pennsylvania. All fieldwork was performed in accordance with the Quality Assurance/Quality Control Plan and Field Procedures Manual (**Appendix E**). Monitoring well locations are shown on **Figure 1-2.** Logs including lithologic information and well construction details are included in **Appendix C**. The following sections discuss the well installation strategy/rationale, and a summary is also available as **Table 3-1**.

AOI 1

In March 2015, three monitoring wells were added to the network in AOI 1. MW-524 and MW-525 were installed along the northwestern (upgradient) site boundary, and MW-526 was installed along the downgradient boundary of AOI 1. Nine additional monitoring wells (MW-542 through MW-550) were installed in August and September 2015, following the completion of the soil boring program. Well locations were selected to delineate the LNAPL plume observed at MW-523, target areas observed to be impacted with LNAPL or exhibiting elevated PID readings during the soil investigation, and to generally increase areal coverage in the former 10 Plant area. The twelve new wells in AOI 1 were installed with screens across the water table.

AOI 2

A network of monitoring wells already existed in AOI 2 prior to the commencement of site characterization activities in February 2015. However, the coverage was increased along the southeastern boundary of AOI 2 and in the 12 Plant Sludge Basin area (SWMU 25) along the western portion of the AOI. In March and April 2015, 12 monitoring wells (MW-511 through MW-522) were installed in these areas to investigate groundwater quality within and downgradient of the 12 Plant Sludge Basin. Wells

installed in this area were screened in the interval between the base of any observed acid sludge and/or the silty-clay layer and the top of bedrock. A fine grained unit is generally observed in this area below fill material and acid sludge, and the goal was to not introduce a conduit for downward migration of acid sludge materials through this local fine-grained unit.

AOI 3

Between July and December 2014, thirteen monitoring wells (MW-487 through MW-495, MW-499 through MW-501, and MW-503) were installed in AOI 3, and one well, MW-502, was installed in AOI 2 as part of the AOI 3 investigation. The goal was to delineate LNAPL plumes to within approximately 200 ft and to increase areal well network coverage downgradient of potential source areas. Monitoring well MW-122, which is located near the eastern property boundary at Green Street, was over drilled and reinstalled on July 28, 2015 in order to rehabilitate the well after it had not been accessed from 1999 to 2014. Additionally, due to the proximity of product-bearing monitoring wells to the eastern downgradient site boundary at Green Street, Evergreen installed four offsite monitoring wells (MW-496 through MW-498, and MW-553) to determine whether LNAPL is present offsite at these locations and monitor downgradient dissolved phase concentrations of COCs. The wells were installed with screens across the water table.

The locations of the monitoring wells in the historical mercury release area (MW-492 and MW-503) were selected following the passive soil gas and surface soil investigation (described in **Section 3.3.4**) in order to target the most impacted locations. These wells were also constructed with extended screen intervals and 2-ft long solid PVC sump below the wells screens in order to collect any free mercury dense non-aqueous phase liquid (DNAPL). No DNAPL has ever been observed in these wells.

AOI 4

In 2013, 52 monitoring wells (MW-376 through MW-423, MW-425, MW-426, MW-429, MW-431 and MW-432) were installed in storage tank containment berms in the AOI 4 tank farms in order to increase areal coverage of the monitoring well network. In 2015, six additional monitoring wells were installed as part of the AOI 4 investigation. MW-504 through MW-508 were installed in AOI 4, and MW-510 was installed in AOI 5.

4.3 GROUNDWATER GAUGING

Stantec conducts annual groundwater and LNAPL gauging of accessible existing wells. The site-wide annual well gauging event, which is typically conducted during the fourth quarter of each year, is used to identify the presence of LNAPL and determine groundwater flow patterns. Liquid level measurements, groundwater contour figures, and product thickness figures are submitted to PADEP in the 2nd Half Semit-Annual Marcus Hook Industrial Complex Groundwater Remediation Status Report. Liquid level measurements collected during the 2013, 2014, and 2015 annual gauging events are provided in **Table 4-3**. Groundwater elevation contours from the October 2014 and 2015 annual gauging events are included as **Figures 2-6** and **2-7**.

In addition to the annual events, groundwater gauging events were conducted in AOIs 1 through 4 prior to characterization groundwater sampling. Characterization gauging events were conducted in AOIs 1 and 2

in May 2015, in AOI 3 in December 2014 and March 2015, and in AOI 4 in July 2013 and April 2015. Data collected during these gauging events, as well as some other gauging events conducted during the remedial investigation timeframe, are shown on **Table 4-3**.

4.4 GROUNDWATER SAMPLING

The following section summarizes the characterization groundwater sampling activities performed in AOIs 1 through 4 between early 2013 and early 2016 by Stantec, Aquaterra, and Langan, in coordination with Evergreen. Fieldwork was performed in accordance with the Quality Assurance/Quality Control Plan and Field Procedures Manual *(***Appendix E**). Monitoring well locations are shown on **Figure 1-2.** Non-product bearing wells were sampled at least twice using the three well volume sampling methodology at intervals at least one quarter apart. Groundwater sampling results, including available historical results, for AOIs 1 through 4 are summarized on **Table 4-2**. Groundwater analytical results from characterization sampling events are described briefly below. Distribution of dissolved COCs will be discussed in detail in **Section 8**.

AOI 1

Wells in AOI 1 were sampled by Stantec on May 27, 2015 and between September 28, 2015 and October 8, 2015. A second round of sampling was conducted on January 5th and 6th 2016 for wells that were installed during August and September 2015. The samples were analyzed for the Evergreen Petroleum Short List and dissolved RCRA metals by Pace Analytical Services, Inc. (Pace; May/June 2015), Eurofins Lancaster Laboratories Environmental, LLC (Lancaster Labs; September/October 2015), and Accutest (January 2016).

In November 2015 and January 2016, three wells (MW-298, MW-425, and MW-429) in AOI 4 were sampled for dissolved arsenic in order to delineate concentrations of this compound that exceeded the SHS at the downgradient boundary of AOI 1 as arsenic was not on the COC list for AOI 4.

Concentrations of the following COCs were detected above the SHS in AOI 1 wells during these events: benzene, ethylbenzene, methyl tert butyl ether (MTBE), toluene, 1,2,4-TMB, naphthalene, and arsenic.

AOI 2

The primary characterization groundwater sampling events for AOI 2 were completed by Stantec between May 28, 2015 and June 2, 2015 and between September 30, 2015 and October 8, 2015. The samples were analyzed for the Evergreen Petroleum Short List and dissolved RCRA metals by Pace (May/June 2015) and Lancaster Labs (September/October 2015).

During the September/October 2015 groundwater sampling event, two wells, MW-495 and MW-98, in AOI 3 were sampled for dissolved arsenic in order to delineate concentrations of this analyte that exceeded the SHS in the 12 Plant Sludge Basin area. The sample from MW-98 was collected from below LNAPL. The procedure for collecting groundwater samples below LNAPL is described in **Appendix E**.

Additional groundwater samples were collected following the September/October 2015 event for wells that were installed following the two main groundwater sampling events, wells that were not accessible

during one of the events, or wells that are intermittently product-bearing. The goal was to complete two rounds of characterization groundwater sampling for the wells.

Concentrations of the following COCs were detected above the SHS in AOI 2 wells during the 2014-2016 characterization groundwater sampling events: benzene, MTBE, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, arsenic, chromium, lead, selenium, and silver.

AOI 3

Groundwater sampling events were conducted by Aquaterra in AOI 3 between December 19 and 31, 2014, and March 3 and 25, 2015. All samples from non-product bearing wells were analyzed for the Evergreen Comprehensive List by Pace.

Samples collected from wells located in the vicinity of the historical mercury release area were also analyzed for dissolved mercury. During the December 2014 event, MW-284, MW-286, MW-287, MW-487, MW-490, MW-494, and Mw-503 were sampled for mercury. During the March 2015 event, the scope of work was expanded to include some product-bearing wells. In addition to the wells sampled for mercury in the December 2014 round, MW-278, MW-491, MW-492, and MW-493 were sampled for mercury using the sub-LNAPL sampling technique. In March 2015, product was detected in MW-503; therefore, the sub-LNAPL sampling technique was also used for this well. Groundwater samples collected under LNAPL for the purpose of characterizing potential source areas for dissolved phase constituents, as opposed to delineation of a dissolved metal, as discussed in **Section 4.5**.

Additional groundwater samples were collected following the March 2015 event for wells that were installed after the two main groundwater sampling events, wells that were not accessible during one of the events, or wells that are intermittently product-bearing. The goal was to complete two rounds of characterization groundwater sampling for the wells.

Concentrations of the following COCs were detected above the SHS in AOI 3 non-product bearing wells during the 2014-2016 characterization groundwater sampling events: benzene, MTBE, 1-2,-dibromoethane (EDB), benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene , bis (2-ethylhexyl)phthalate, and vanadium. Dissolved lead (MW-553) and zinc (MW-497) were detected above the SHS in offsite monitoring wells located to the northeast of AOI 3.

AOI 4

Characterization groundwater sampling events were conducted by Aquaterra in AOI 4 between July 18 and 25, 2013, and April 6 and 21, 2015. Groundwater samples were analyzed by Pace. During the July 2013 event, all samples were analyzed for the Evergreen Petroleum Short List parameters. During the April 2015 sampling event, the analyte list was expanded for some wells to the Evergreen Comprehensive List. Groundwater analytical results from 2011 sampling events were used as the first round of characterization data for some wells.

Concentrations of the following COCs were detected above the SHS in AOI 4 wells during the 2011-2016 characterization groundwater sampling events: benzene, EDB, 1,2,-dichloroethane (EDC), ethylbenzene, MTBE, 1,2,4-TMB, toluene, xylenes, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, naphthalene, pyrene, quinoline, lead, and vanadium.

4.5 SUB-LNAPL GROUNDWATER SAMPLING

In order to investigate potential sources of dissolved phase COCs and to obtain data to be used in future groundwater to surface water modeling, groundwater samples were collected below representative LNAPL plume areas in the AOIs located in proximity to the Delaware River. In 2015, sub-LNAPL groundwater samples were collected from MW-19 in AOI 2, and RW-26, MW-33, MW-98, MW-491, and MW-492 in AOI 3. The procedure for collecting samples in groundwater below LNAPL is described in **Appendix E**. The results from these sampling events are included on **Table 4-2** and can be identified by the qualifier "SL". The results will be discussed further in **Section 8.0**.

5.0 LNAPL INVESTIGATION

To investigate LNAPL in AOIs 1 through 4, a comprehensive LNAPL Conceptual Site Model (LCSM) was prepared and is included as **Appendix I** of this RIR. In general, the LCSM utilizes a technical approach to evaluate the potential mobility of LNAPL present at the site incorporating multiple lines-of-evidence including observations of LNAPL distribution over time, dissolved plume characteristics, an analysis of apparent LNAPL thickness, physical and chemical laboratory analysis of LNAPL samples, and theoretical estimates of LNAPL mobility to understand whether AOIs 1 through 4 LNAPL areas are residual (immobile), mobile, and/or migrating. As defined in the LCSM, residual LNAPL in AOIs 1 through 4 represents LNAPL that is trapped in soil pores, mobile LNAPL is LNAPL that exceeds residual saturation, and migrating LNAPL is LNAPL that is observed to spread or expand. It is noted that although mobile LNAPL includes migrating LNAPL, not all LNAPL indicated to be mobile is migrating.

The following summarizes findings and conclusions of key elements of the LCSM utilizing data gathered from literature review, historical and recent field investigations, laboratory analyses, and remediation efforts. **Figures 5-1, 5-2a** through **5-2e**, and **5-3** and **Table 5-1** are provided to support the summary.

5.1 LNAPL DISTRIBUTION

Figures 5-2a through **5-2e** present the apparent LNAPL thickness in wells located within AOI 1 through AOI 4 in 2015. Additionally, **Table 4-3** presents the water level and LNAPL thickness measurements collected from 2013 through 2015. In addition to these figures/tables, the LCSM (**Appendix I**) presents a historical summary of the areal distribution of LNAPL over time broken up into two year intervals from 1999 to 2015. **Figures 5-2a** through **5-2e** display each monitoring well that was gauged in 2015 and use symbology to differentiate the following:

- Measureable LNAPL apparent thickness,
- LNAPL sheen,
- Wells with submerged screens (the screened interval is entirely below the top of the water table and therefore is not a reliable indicator of the presence or absence of LNAPL), and
- Dissolved benzene samples with concentrations indicative of LNAPL (see **Appendix I**).

Since 1999, LNAPL has been detected in 173 of 323 wells (54%) at the Site. In 1999, LNAPL was detected in 53 of 87 gauged wells (61%) while in 2015 LNAPL was detected in 93 of 292 gauged wells (32%) (**Appendix I**). The general decrease in the number and extent of wells with measureable LNAPL apparent thickness indicates that the LNAPL mobility is low and reflects the results of remediation and natural source zone depletion at the Site.

The distribution of LNAPL at the Site has been assessed up gradient to the northwest in AOIs 1 and 4 by a series of wells located along Ridge Road. LNAPL has not been detected in these wells and benzene samples from these wells have not been indicative of the presence of LNAPL. Key wells without LNAPL to the northwest include MW-504, MW-524, MW-525, and MW-62 (**Figure 5-2a**).

To the northeast (cross-gradient), the extent of the LNAPL plumes has generally been assessed by wells without LNAPL located along either side of Green Street and Rennie Lane. Additionally, subsurface features may influence the extent of LNAPL in this direction. For example, there is an 84-inch sewer located east of the Green Street Remediation System which is thought to intersect the water table and may be acting as a barrier to easterly LNAPL migration. Key wells that provide LNAPL delineation to the northeast include:

- MW-502, MW-108 which are located onsite east of MW-101 in AOI 2 (**Figure 5-2b**);
- SP-2B, MW-499, RW-19, MW-500, MW-27, MW-28, and MW-501 which are located onsite in AOI 3 (**Figure 5-2c**); and
- MW-496, MW-497, MW-498, and MW-553 are located offsite to the east of AOI 3 (**Figure 5-2c**).

To the southeast (downgradient), the extent of the LNAPL plumes has generally been assessed by wells located along the Delaware River. These wells include MW-28 (which has only exhibited LNAPL twice and not since 2008), MW-29 (which has occasionally and recently been submerged), MW-30 (which has only had LNAPL detected one time in 2005 which is thought to have been anomalous), and MW-489 (**Figure 5-2c**).

To the southwest (cross-gradient) the extent of the LNAPL plumes on AOI 2 and AOI 3 has been assessed by other AOIs not included in the scope of this report (AOI 5, AOI 6) (**Figures 5-2b** and **5-2c**). The southwest extent of LNAPL plumes on AOI 4 is defined by MW-364 (onsite), MW-365, MW-366, and MW-367. Well MW-373 does not have LNAPL and is located to the southwest of MW-409 which has recently had LNAPL detected (**Figures 5-2d** and **5-2e**).

5.2 LNAPL SOURCE

The current and historic uses of the areas of AOIs 1 through 4 impacted with LNAPL provide some indication of the potential LNAPL sources. Many different types of petroleum products have been handled and LNAPL from various sources may be commingled.

LNAPL characterization samples have generally indicated that the LNAPL has been degraded. Of the 14 LNAPL samples where the degree of weathering was reported, only one sample has been classified as slightly weathered (MW-197) (**Appendix I**). LNAPL associated with older, more weathered, and degraded releases are generally less mobile.

The following summarizes available information from the historical record regarding potential LNAPL sources.

AOI 1

LNAPL has been detected in three of the 17 monitoring wells present in AOI 1 (MW-94, MW-523, and MW-545) and elevated concentrations of benzene have been detected in three additional wells (MW-543, MW-546, and MW-549).

Historically, AOI 1 included the 10-4 Catalytic Cracking Unit which was used to "split long chain hydrocarbons into high octane compounds for gasoline and fuel oil blending" (A.T. Kearney, 1991). The exact source of the LNAPL in AOI 1 is unknown, however, it is likely related to one of the SWMUs or various potential underground sources. The LNAPL detected at MW-523 is likely related to the middle distillate plume present in the northeastern portion of AOI 4.

AOI 2 and AOI 3

LNAPL has historically been detected in AOI 2 only in the southeast corner of the AOI adjacent to AOI 3, in wells MW-19 and MW-101, and in or directly adjacent to the acid sludge waste used as fill in the 12 Plant Sludge Basin (SWMU 25; wells MW-229 through MW-231).

LNAPL has historically been detected in several areas of AOI 3 including:

- In the vicinity of the Refinery Lab Research and Development Building and Main Office Building,
- In the vicinity of the Green Street interceptor trench extending into the southeastern corner of AOI 2, and
- In the northwestern area of AOI 3.

Acid sludge waste is a potential source of LNAPL in or directly adjacent to the 12 Plant Sludge Basin, while Slop Oil Tanks V-29, 132, 137, and 139 are potential sources of LNAPL in the northwestern part of AOI 3, and the source of LNAPL near the Refinery Laboratory remains unclear. Potential sources for the LNAPL encountered along Green Street and extending into the southeastern corner of AOI 2 include:

- Clay Contact Plant Area (SWMU 57), which was used "to remove acids caustics, sulfonates, water and aromatics from specialty oils and had a hydrocarbon content of approximately 30%" (A.T. Kearney, 1991).
- Historical ASTs located to the northeast of the Clay Contact Plant Area
- 8-C Crude Unit, which was located adjacent to and downgradient from MW-123 and MW-124
- Process sewer lines and a storm sewer line which ran from AOI 2 southeast to AOI 3 within less than 50 feet of wells with LNAPL.

AOI 4

LNAPL has been detected in areas along Post Road in AOI 4 and adjacent to AOI 1. Potential sources for the LNAPL encountered in AOI 4 include the numerous ASTs and above and below ground pipelines present in the area, and the Auto Lab. The LNAPL present near the AOI 1 boundary is likely related to piping and/or the H-1 pump house. LNAPL collected from MW-197 was characterized as slightly weathered.

5.3 LNAPL CHARACTERIZATION

Various petroleum products have been stored, processed, and distributed throughout AOIs 1 through 4. The LNAPL observed at the Site is expected to be made up of various combinations of these products and is expected to have been modified from its source material by the effects of commingling, weathering, dilution, and differential solubility.

LNAPL characterization sampling has been completed for 22 wells at the Site (**Table 5-1** and **Figures 5-1** and **5-3**). Interpretation of the LNAPL characterization results has provided estimates of the LNAPL source materials within each sample, and these results are helpful when identifying LNAPL sources. To facilitate visualization of the results it is helpful to generalize the LNAPL characterization results into categories. Below is a summary of the generalized LNAPL characterization types used to group LNAPL present in AOIs 1 through 4.

- Light Distillates: Light distillates include LPG, gasoline, and naphtha. LNAPL types grouped into the light distillate category include samples that have been primarily characterized as gasoline, heavy virgin naphtha or reformed light naphtha. The primary components included in these products generally have carbon numbers (the number of carbon atoms in each molecule) between 3 and 10.
- Mixes of Light/Middle Distillates: The samples grouped into the light/middle distillate category include samples that were characterized to be intermediate mixes of light and middle distillate products.
- Middle Distillates: Middle distillates include kerosene, jet fuel, diesel fuels, and light (#2) fuel oils. The LNAPL types grouped into the middle distillate category include samples that characterized to be primarily middle distillate or that include significant proportions of coker naphtha mixed with middle distillate. The primary components included in these products generally have carbon numbers between 9 and 20.
- Heavy Distillates: Heavy distillates include heavier (#4 & #6) fuel oil and heavy atmospheric gas oil. The LNAPL types grouped into the heavy distillate category include samples that were characterized as lubricating oil, residual oil, and heavy distillate. The primary components included in these products have carbon numbers between 14 and 40.
- Residuum (not present in AOIs 1 through 4): Include waxes and asphalts. The primary components included in these products have carbon numbers ranging from approximately 24 to greater than 40.

AOI 1

The 2012 CCR classified the LNAPL present in southwestern AOI 1 as gasoline (Light Distillate) (Langan, 2012a). An LNAPL characterization and density sample was collected from MW-523, located in the western portion of AOI 1, in April of 2015. Pace Analytical characterized the sample as a Middle Distillate (Appendix I) with a specific gravity of 0.884. The 2015 results are interpreted to be representative of the LNAPL present at MW-523 as well as the other wells in AOI 1 (MW-545) and were consistent with the characterizations results for three wells in the northern corner of AOI 4 (MW-399, MW-400, and MW-404).

AOI 2

West-central: A LNAPL characterization and density sample was collected from MW-231 in December of 2015. Pace Analytical characterized the sample as a type of degraded Heavy Distillate with a specific gravity of 0.93 (Appendix I). This is consistent with the expected source of the LNAPL in this area (acid sludge waste used as fill in the 12 Plant Sludge Basin [SWMU 25]).

Southeastern Corner: The 2012 CCR classified the LNAPL present in the southeastern corner of AOI 2 as a gasoline/diesel mix (Light/Middle Distillate) (Langan, 2012a). A LNAPL characterization and density sample was collected from MW-19 in December of 2015. Pace Analytical characterized the sample

as a type of degraded Heavy Distillate with a specific gravity of 0.92 (**Appendix I**). The LNAPL present in the southeastern corner of AOI 2 is interpreted to be a type of Heavy Distillate.

AOI 3

The 2012 CCR classified the LNAPL present in AOI 3 as a Gasoline/Diesel mix (Light/Middle Distillate) (Langan, 2012a). LNAPL characterization results from 12 wells in AOI 3 included wells classified as Light/Middle Distillate, Middle Distillate, and Heavy Distillate. Based on the LNAPL characterization results, there appears to be various generalized LNAPL types distributed around AOI 3. Within the central (MW-289, MW-266, and RW-26) and northern (MW-98) area of AOI 3 the LNAPL is consistent with the 2012 CCR classification as a Light/Middle Distillate. In the northwest of AOI 3, the LNAPL in recently sampled wells (MW-491, MW-492, and MW-285) was classified as Middle Distillate. To the southwest (bordering AOI 6, MW-33) and northeast (along Green Street, MW-19 and P-3) in AOI 3, the 2015 LNAPL sampling indicates Heavy Distillates are present.

AOI 4

H-5 System Area: The 2012 CCR classified the LNAPL present in the H-5 system area as gasoline (Light Distillate) (Langan, 2012a). LNAPL characterization and density samples have been collected from MW-169 and MW-197. Pace Analytical characterized the sample from MW-169 as a type of Middle distillate with a specific gravity of 0.916 (**Appendix I**). The sample from MW-197 was characterized as a Light/Middle Distillate with a density of 0.85.

12 Tank System Area: The 2012 CCR classified the LNAPL present in the 12 Tank system area as diesel (Middle Distillate) (Langan, 2012a). An LNAPL characterization sample collected from RW-148 was classified as diesel with a specific gravity of 0.85 by Lancaster Labs (**Appendix I**).

Northern Corner: As mentioned in the section above for AOI 1, three characterization samples were collected in this area near H-1. Samples from MW-399, MW-400, and MW-404 were characterized by Torkelson Geochemistry, Inc as diesel (Middle Distallate), which is consistent with the characterization of the product in MW-523.

Auto Lab Area: The 2012 CCR classified the LNAPL present in the Auto Lab area as gasoline (Light Distillate) (Langan, 2012a). A LNAPL characterization and density sample was collected from MW-409 in November of 2015. Pace Analytical characterized the sample as light distillate with a specific gravity of 0.716 (Appendix I).

5.4 LNAPL MOBILITY

In addition to the primary lines of evidence used in evaluating LNAPL plume stability mobility described above (LNAPL distribution and characterization), secondary lines of evidence were also evaluated in the LCSM (**Appendix I**). These secondary lines of evidence include LNAPL transmissivity estimates, LNAPL mobility term evaluation, LNAPL pore entry pressure evaluation, LNAPL mobility modeling, and LNAPL distribution and recovery modeling (LDRM). A summary of the results of the secondary lines of evidence evaluation is presented below and are presented in greater detail in **Appendix I**.

- Site-specific values of LNAPL transmissivity have been estimated from historical LNAPL/groundwater recovery ratios from dual-phase and total fluid extraction wells. The results indicate a decreasing trend with current values below or approaching the limit of practicable recovery. The most recent estimates of average LNAPL transmissivity for the AOI 3 Laboratory Building Remediation System are less than 0.02 ft^2/day, compared to the historical maximum estimated LNAPL transmissivity of 0.86 ft^2/day in 2005. The most recent estimates of average LNAPL transmissivity for the AOI 4 12-Tank Remediation System are less than 0.001 ft^2/day, compared to the historical maximum estimated LNAPL transmissivity of 0.016 ft^2/day in 2004. The most recent estimates of average LNAPL transmissivity for the AOI 4 H-5/Post Road recovery system are 0.3 ft^2/day, compared to the historical maximum estimated LNAPL transmissivity of 8.4 ft^2/day in 2006. The estimates are based on average extraction rates for each remedial system operating as a whole. The estimates are made conservative and use the maximum estimated aquifer transmissivity based on literature estimates of hydraulic conductivity using site-specific lithologic data.

- A conservative value for the site-specific mobility term was calculated to be $1.187x10^{-1}$ cm^3s/g, which is above the practical limit of mobility.

- The critical pore entry pressure was estimated for wells that had greater than 0.5 feet of apparent LNAPL thickness in 2015. The estimated critical pore entry pressure thicknesses ranged from 0.33 to 23.69 feet with an average of 5.92 feet. For 27 of the 92 wells evaluated, the observed LNAPL thickness was greater than the critical pore entry pressure indicating that the LNAPL observed at these wells may be mobile.

- As part of the LCSM, plume velocity calculations were updated for wells with greater than 0.5 feet of apparent LNAPL thickness in 2015. Model-calculated plume velocities ranged from $8.6x10^{-10}$ cm/s to $5.6x10^{-4}$ cm/s with an average velocity of $4.1x10^{-5}$ cm/s. ASTM suggests that LNAPL seepage velocities less than $1x10^{-6}$ cm/s indicate that the LNAPL is functionally immobile. The estimated velocity for 25 of the 76 wells evaluated was greater than the limit of functional mobility. Based on this criterion, the model results indicate that the plume may be able to migrate at its leading edge near those locations.

- The API LDRM model was run for wells with greater than 0.5 feet of apparent LNAPL thickness in 2015. Of the 76 wells evaluated, 17 have LNAPL transmissivity values within the practicably recoverable range, 2 wells have LNAPL transmissivity values within the lower transitional end of practicable recoverability, and 57 wells are in the not practicably recoverable range. The wells with LDRM estimated LNAPL transmissivities in the practicably recoverable range are all located in AOI 3.

Based upon the multiple lines of evidence, the LNAPL present is generally not migrating and not practicably recoverable. However, LNAPL present at several areas in AOIs 1 through 4 (that are distal to active remediation systems) may be mobile, able to migrate, and recoverable based on trends of increasing LNAPL thickness, calculations showing LNAPL thickness exceeding the critical pore entry pressure, and/or calculations showing the estimated plume velocities are greater than the ASTM limit of functional mobility. These areas include:

- The downgradient edge of the Refinery Laboratory Remediation System area (MW-488, MW-97, and MW-271);
- MW-25 which is along the eastern edge of AOI 3; and
- The Auto Lab area of AOI 4 (MW-359, MW-360, MW-362).

6.0 VAPOR INTRUSION PATHWAY INVESTIGATION

6.1 INDOOR AND AMBIENT AIR SAMPLING

6.1.1 Selection of Air Sampling Locations

In order to access whether a complete pathway exists for volatilization of hydrocarbons to indoor air, indoor air samples were collected in onsite occupied buildings. The size, construction, and use of all the buildings in AOIs 1 through 4 were evaluated in order to identify which buildings contained potential receptors for volatilization to indoor air. Of the 34 buildings evaluated, nine buildings were identified as requiring further evaluation of the vapor intrusion pathway. Building details are summarized on **Table 6-1**, and building locations are shown on **Figures 6-1** and **6-2**.

Twenty-five buildings were excluded from further evaluation of the vapor intrusion pathway. The 10 Plant Control Room (AOI 1), No. 2 Substation (AOI 1), 12 Plant Control Room (AOI 2), Zone 4 Shop (AOI 2), 8C Shop (AOI 3), Brick Electrical Building (AOI 3), Fire Suppression Buildings (2 in AOI 3), Former Safety Store (AOI 3), Research and Development (R&D) Outbuilding 2 (AOI 3), R&D Outbuilding 3 (AOI 3), Refinery Laboratory (AOI 3), Second Street Shop Safety Store/Security Warehouse (AOI 3), Semi-Works Building 1 (AOI 3), Semi-Works Heated Storage (AOI 3), Semi-Works Open Storage (AOI 3), Spill Response Center (AOI 3), Hardwoord Storage Building 286 (AOI 4), Storehouse Building 288 (AOI 4), Building 291 (AOI 4), and Building 292 (AOI 4) were excluded from the indoor air sampling program because they are all unoccupied.

Four other buildings were excluded. The Contractor Processing Trailer was excluded because it was demolished in 2015. Semi-Works Building 2 and Semi-Works Building 3 were excluded because they are located greater than 30 feet from an LNAPL plume and concentrations of COCs in nearby monitoring wells are below thePADEP Groundwater Site Specific Standard Vapor Intrusion Screening Values, Non-Residential (SVGW-NR) presented in the VI Guidance (PADEP, effective 2017). The Guard Shack was excluded from the indoor air sampling program because it represents a quasi-outdoor space, with constant air flow-through. In 2016, the Guard Shack was replaced with an elevated shed structure which was also excluded due to constant flow-through of air below the building.

Although the R&D Building is unoccupied, it was included for indoor air sampling due to its future potential for occupation and proximity to an LNAPL plume. Buildings that were determined to be occupied, and therefore warranted additional investigation, were as follows:

AOI 2
- Sunoco Race Fuels Blending Plant

AOI 3
- Chicago Bridge & Iron (CBI) Main Office Trailer (selected as representative example of various skirted contractor trailers within AOI 3)
- Fire House
- Headquarters
- Main Office Building (4 sections)

- R&D Outbuilding 1: Fitness Center and Distillation Laboratory

AOI 4
- H-5 Building
- Auto Lab

Indoor air sampling was not necessary in AOI 1. Indoor air sampling was performed in AOIs 2 and 3 on March 12, 2015 and in AOI 4 in September/August 2013 and February 4, 2015. Samples collected in March and February would be expected to represent most conservative indoor conditions during the heating season. All samples were collected from the lowest level of the respective structure and in accordance with The Quality Assurance/Quality Control Plan and Field Procedures Manual (**Appendix E**). Sample locations are shown on **Figures 6-1** and **6-2**. AOI 2 and 3 samples were analyzed for volatile organic compounds (VOCs) on the Evergreen Comprehensive list by EPA method TO-15, and AOI 4 samples were analyzed for the full TO-15 list. Results for the Evergreen Comprehensive list parameters are summarized on **Table 6-2**, and laboratory analytical reports are included in **Appendix F**.

In addition to the indoor air samples collected in AOIs 2 and 3, seven ambient air samples were collected. AOI2_AOI3_AA-01 and AOI2_AOI3_AA-02 were collected in the upwind and downwind direction, respectively, of AOIs 2 and 3, as measured on March 12, 2015. In order to evaluate the pathway for volatilization to outdoor air, three ambient air samples were collected above LNAPL plumes in the vicinity of parking lots and office buildings. Sample AOI3_AA-03 was collected above the LNAPL plume located near the Main Office Building, sample AOI3_AA-04 was located above LNAPL occurring near the Green Street Sewer area and the southern contractor parking lot, and sample AOI2_AA-05 was located above LNAPL occurring the southeastern corner of AOI 2 between the two contractor parking areas. Two samples, AOI3_AA-06 and AOI2_AA-07, were collected to evaluate ambient air in the vicinity of indoor air samples. One additional sample was designated as a field blank. All sample locations are shown on **Figure 6-1**.

Two ambient air samples were collected during each of the AOI 4 events. These samples (BG-IA1 and BG-IA2 in 2013 and BH-H5 and BG-AL in 2015) were collected to evaluate ambient air in the vicinity of indoor air samples. In addition, two ambient air samples were collected during the Verizon vault sampling event (VSV-BG1 and VSV-BG2) and three ambient air samples were collected during the PECO vault sampling event (PSV-BG1 through PSV-BG3). All sample locations are shown on **Figure 6-1**.

6.1.2 Indoor and Ambient Sample Results

The analytical results of the indoor and ambient air sampling are briefly discussed below. All of the analytical results are presented on **Table 6-2** and the laboratory analytical report is included in **Appendix F**. Seven sets of screening values are provided for reference:

- EPA RSL, TR=1E-5, THQ=0.1
- EPA RSL, TR=1E-6, THQ=0.1
- SVIA-NR SHS
- SVIA-NR SSS
- OSHA PEL
- NIOSH REL

- ACGIH TLV

The Land Recycling Program Technical Guidance Manual for Vapor Intrusion into Buildings from Soil and Groundwater under Act 2 (VI Guidance; PADEP, effective 2017) establishes the EPA RSLs, TR=1E-5, THQ=0.1 as appropriate screening values when it can be demonstrated that vapor intrusion is the only complete exposure pathway for a receptor. Upon the completion of remediation activities, volatilization to the breathing zone will be the only potentially complete pathway for petroleum impacts in AOIs 1 through 4. A calculated site specific standard is not being used except for lead in soil, which is not a potential vapor intrusion concern.

Background indoor air concentrations are also used as a point of reference for evaluating both ambient and indoor air results. Background concentrations in indoor air vary by the historic use and operation of a building. Background indoor air in industrial or commercial spaces is not commonly studied or evaluated; however, EPA did compile and evaluate background indoor air concentrations in North American residences (EPA, 2011). These data are used as a conservative point of reference when evaluating ambient and indoor air results, and statistical information from the EPA compilation is shown with the results from onsite air sampling on **Table 6-3**.

6.1.3 Ambient Air Results

The concentrations of VOCs detected in ambient air were lower than the corresponding EPA RSLs, TR=1E-5 in all samples with the exception of naphthalene in two samples. Naphthalene was detected above the EPA RSL, TR=1E-5 of 1.3 µg/m^3 at concentrations of 1.4 µg/m^3 and 2.2 µg/m^3 in samples AA-04 and BG-IA1, repectively. AA-04 was located in the contractor's parking area in AOI 3 and BG-IA1 was located near the H-5 Building in AOI 4. The concentrations of VOCs detected in ambient air were at least two orders of magnitude lower than the corresponding occupational exposure standards. Background ranges are not available for naphthalene.

PADEP operates a network of air toxics monitoring stations that sample for VOCs. Note that several COCs are not included in PADEP's monitoring program. Detailed analytical results by year for each monitoring station are available on-line at http://www.dep.pa.gov/Business/Air/BAQ/MonitoringTopics/ToxicPollutants/Pages/Toxic-Monitoring-Sites-in-Pennsylvania.aspx . Regional ambient air quality in the Marcus Hook Industrial Complex is best represented by data from the Marcus Hook monitoring station (latitude 39.8178, longitude - 75.4142). **Table 6-4** presents the results for the ambient air samples with the air toxics monitoring data for the closest available date. The concentrations of petroleum-related compounds in the outdoor air at the facility were somewhat higher than regional mean background as represented by concentrations reported from PADEP's Marcus Hook monitoring location. This is particularly true in AOI 4.

6.1.4 Indoor Air Results

With the exception the one sample in the Fire House building, the concentrations of VOCs detected in the indoor air samples collected from all buildings sampled within AOIs 2 and 3 were lower than the corresponding EPA RSLs, TR=1E-5 and were at least one order of magnitude lower than corresponding

occupational exposure standards. Results for 1,3,5-TMB were screened against the SVIA-NR SSS because there is not an established EPA RSL for this compound. In the sample collected in the Fire House office (AOI3_AI-05) 1,2,4-TMB was detected above the EPA RSLs, TR=1E-5 (3.1 µg/m^3) at a concentration of 15 µg/m^3, and 1,3,5-TMB was detected above the SVIA-NR SSS (3.1 µg/m^3) at a concentration of 4.4 µg/m^3 . It should be noted that the sample collection location in the Fire House is in an office adjacent to the vehicle storage area; therefore, these detections may be a result of a background condition. Also in sample AOI3_AI-05, benzene and 1,2,4-TMB were detected above the more conservative EPA RSLs, TR=1E-6 at concentrations of 1.8 µg/m^3 and 15 µg/m^3, respectively. EDC was detected above the EPA RSL, TR=1E-6 in the CBI Main Office Trailer at a concentration of 1.7 µg/m^3, and above the range of concentrations observed in the EPA background indoor air study compilation (**Table 6-3**). The concentrations of benzene detected were within the range observed in the EPA background indoor air study compilation (**Table 6-3**). Background ranges are not available for 1,2,4-TMB or 1,3,5-TMB.

In AOI 4, concentrations of VOCs detected in the indoor air samples collected from the Auto Lab building were lower than the corresponding EPA RSLs, TR=1E-5. Benzene was detected above the EPA RSLs, TR=1E-6 in all three samples collected from the Auto Lab building in 2015 at concentrations ranging from 1.73 to 2.24 µg/m^3, which are within the EPA background ranges and are lower than the concentration of benzene detected in ambient air near the Auto Lab building, which was 3.55 µg/m^3 in sample BG-AL.

In the H-5 Building in AOI 4, benzene was detected above the EPA RSL, TR=1E-6 in all samples collected. EDC, naphthalene, and 1,2,4-TMB were also detected above the EPA RSLs, TR=1E-6 in samples collected from this building. Two samples had concentrations of COCs above the EPA RSLs, TR=1E-5; benzene was detected at concentrations exceeding the EPA RSLs, TR=1E-5 of 13 µg/m^3 in two samples collected in February 2015. These samples were the H5-Control Room (23.6 µg/m^3) and in the duplicate sample for H5-Decom (16.8 µg/m^3). However, the concentration in the H5-Decom primary sample was below the EPA RSLs, TR=1E-5 at a concentration of 12.5 µg/m^3. Naphthalene and 1,2,4-TMB were detectected above their respective EPA RSLs TR=1E-5 of 1.3 µg/m^3 and 3.1 µg/m^3 in four samples collected in August 2013. These sample results for naphthalene and 1,2,4-TMB were the H5-Control Room (2.0 µg/m^3 and 3.7 µg/m^3) the the H5-Control Room duplicate (1.9 µg/m^3 and 3.5 µg/m^3), H5-Decom (2.3 µg/m^3 and 3.8 µg/m^3), and H5-Office2 (2.1 µg/m^3 and 3.8µg/m^3), respectively. The elevated concentrations of benzene detected in the H5 building are both within the range observed in the EPA background indoor air study compilation (**Table 6-3**). Background ranges are not available for naphthalene or 1,2,4-TMB. All concentrations of COCs detected in AOI 4 were at least two orders of magnitude lower than corresponding occupational exposure standards.

Laboratory reporting limits for some additional compounds were above the EPA RSLs, TR=1E-5 in some buildings. Options to address these compounds will be presented in the Cleanup Plan.

6.2 AIR SAMPLING IN UNOCCUPIED SPACES

To gather supplementary information relevant to vapor intrusion, additional unoccupied spaces were screened for VOCs.

6.2.1 AOI 3: R&D Building

In AOI 3, two samples, AOI3_AI-06 (basement) and AOI3_AI-07 (first floor), were collected from the currently unoccupied R&D building during the March 2015 air sampling event described in **Section 6.1**. Currently, access to the building is restricted and significant rehabilitation would be necessary for it to be a habitable space. The purpose of these samples was to understand what the baseline concentrations of VOCs are in the building should it be decided that the building would be brought back into use. Results are presented on **Table 6-2**. Concentrations of COCs were not detected above the EPA RSLs, TR=1E-5 in either of the samples.

6.2.2 AOI 4: Utility Conduit Sewer Investigation

Soil gas/ vapor was sampled in the utility conduits along Post Road in order to evaluate potential hazards for utility workers. Vapor sampling was conducted during August 2013 and September 2013. Nine samples, PSV-1 through PSV-9, were collected from utility vaults owned by PECO, and ten samples, VSV-1 through VSV-10, were collected from utility vaults owned by Verizon. Sample locations are shown on **Figure 6-1**, analytical results are summarized on **Table 6-2**, and laboratory reports are available in **Appendix F**.

6.2.2.1 Utility Conduit Vapor Sampling Methods

The soil gas/vapor samples were collected by inserting ¼-inch diameter polyethylene tubing down into the conduit sewer through an access hole on the manhole cover. Modeling clay was placed around the tubing to seal any void space between the tubing and access hole. In preparation for sampling, the polyethylene tubing from the conduit was connected to a stainless steel "T" fitting with an in-line valve. The opposite ends of the "T" fitting were connected to a low flow air purge pump, and to a laboratory-supplied, batch-certified 1-liter Summa canister with a flow regulator calibrated to collect a sample corresponding to a 5-minute sample time, which was a rate of 200 ml/min (milliliters per minute). The advantage of the "T" fitting configuration is that it allows the polyethylene tubing to be purged, and the sewer vapors sampled, without disconnecting the tubing. Note that all Summa canisters and flow regulators were calibrated by the analytical laboratory, and each Summa canister was checked to ensure that it was under sufficient vacuum (approximately -25 to -30 inches of mercury) prior to sample collection. Three tubing volumes were purged from the conduit vapor sample point using the low flow air purge pump calculated to purge at a maximum rate of 200 ml/min. Upon completion of the purge, the direction of the valve in the "T" fitting was reversed, and sample collection began.

A helium tracer test was performed prior to and throughout sampling to ensure the annular space between the tubing and the access hole on the manhole cover was properly sealed, thereby ensuring a representative sample. The helium tracer test was performed by placing a plastic shroud over top of the access hole on the manhole cover. The polyethylene tubing from the sewer was run out of the shroud and connected to the stainless steel "T" fitting. Helium was pumped into the shroud. A helium detector inserted into the shroud monitored continuous concentrations within the shroud. A helium concentration reading was collected from the air purge pump outlet. If the helium concentration of the purge gas was

greater than 5% of the concentration within the shroud, corrective action was taken to create a tighter seal.

In order to evaluate potential background conditions, two ambient air samples were collected during the Verizon vault sampling event (VSV-BG1 and VSV-BG2) and three ambient air samples were collected during the PECO vault sampling event (PSV-BG1 through PSV-BG3). The air flow rate for the ambient air Summa canister was controlled with a laboratory-certified flow controller calibrated to collect a sample at a rate of 11 ml/min (corresponding to an 8-hour sample time).

The soil gas/ vapor samples and the ambient air samples collected were analyzed for VOCs using USEPA Method TO-15.

6.2.2.2 Utility Conduit Vapor Sampling Results

Concentrations of COCs were detected above the EPA RSLs, TR=1E-5 at thirteen of the utility conduit vapor sampling locations. The COCs detected above EPA RSLs, TR=1E-5 were benzene, cyclohexane, ethylbenzene, m,p-xylenes, hexane, naphthalene, and 1,2,4-TMB. Results for 1,3,5-TMB were screened against SVIA-NR SSS because there is not an established EPA RSL for this compound. 1,3,5-TMB was detected above SVIA-NR SSS in one sample (PSV-2). Results were also compared to occupational exposure standards. One concentration of benzene was detected above the NIOSH REL of 319 µg/m^3 in sample VSV-5. However, the concentration detected, 416 µg/m^3, is lower than both the OSHA PEL and the ACGIH TLV.

6.3 H-5/POST ROAD REMEDIATION SYSTEM

The H-5/Post Road Remediation System includes a soil vapor extraction (SVE) component which consists of a network of approximately 20 wells located around the H-5 Control Room and along Post Road. It was constructed to remove vapors from a utility manhole adjacent to Post Road as well as the H-5 Control Room. The H-5 Control Room SVE system currently has a sub-floor blower system in addition to vapor recovery from wells RW-247, RW-248, RW-249, RW-251, RW-252, RW-253, RW-254 and RW-255. Additional detail regarding the system is available in **Appendix J**.

6.4 VAPOR INTRUSION POTENTIAL TO OFFSITE RECEPTORS

Offsite receptors for volatilization to indoor air are potentially of concern along the Green Street property boundary due to the presence of potential preferential pathways and an easterly component of groundwater flow in some areas along the property boundary. **Figures 6-1** and **6-2** show the locations of known utilities at the Green Street property boundary. More detailed information is available for the area near the northern corner of AOI 3. Due to the presence of LNAPL near the property boundary, the Pennsylvania One Call system was used to obtain information regarding utility locations. **Figures 6-1** and **6-2** also show the location of the 84-inch sewer that runs along Green Street, including the locations of lateral connections that could indicate additional pathways. It is expected that options to address the movement of vapors along preferential pathways will be addressed in a future Act 2 deliverable.

Residential exposure to VOCs in indoor air resulting from volatilization of dissolved VOCs in groundwater is also a potential concern offsite. In order to evaluate this potential pathway, groundwater results from the property boundary wells and offsite Green Street area wells were screened against the PADEP Groundwater Site SpecificStandard Vapor Intrusion Screening Values, Residential (SVGW-R). The results of this screening are summarized on **Table 6-5**, and colorized representations of the results of this screening over the past five years are depicted on **Figures 6-1** and **6-2**. Concentrations of VOCs in groundwater are below the screening values for all Evergreen Comprehensive List COCs with the exception of benzene and 1,2,4-TMB in the following instances:

- MW-297 (AOI 1): Benzene was detected above the SVGW-R in a sample collected in 2011, but has not been detected above the residential groundwater MSCs in samples collected from 2012 to 2015.
- MW-11 (AOI 2): Benzene was detected above the SVGW-R in samples collected from 1995 through 1998, but has not been detected above the SVGW-R in samples collected from 2003 to 2015.
- MW-12 (AOI 2): Benzene was detected above the SVGW-R in a sample collected in 1999, but has not been detected above the SVGW-R in samples collected from 2011 to 2015.
- MW-13 (AOI 2): Benzene was detected above the SVGW-R in samples collected from 1995 through 2013 , but has not been detected above the SVGW-R in samples collected from 2014 to 2016. 1,2,4-TMB was detected above the SVGW-R in samples collected in 2010 through 2012, but has not been detected above the SVGW-R in samples collected from 2013 through 2016. Ethylbenzene was detected above the SVGW-R in samples collected in 1995 and 1996, but concentrations of this constituent have been non-detect or below the SVGW-R for the last 20 years.
- MW-300 (AOI 2): Benzene was detected above the SVGW-R in the sample collected in 2011, but has not been detected above the SVGW-R in samples collected from 2012 to 2015.
- MW-74 (AOI 3): Benzene was detected above the SVGW-R in the sample collected in 2003, but has not been detected above the SVGW-R in samples collected in 2004 and 2011.
- MW-122 (AOI 3): Benzene was detected above the SVGW-R in samples collected in 2015.
- MW-553 (AOI 3, offsite): Benzene was detected above the SVGW-R one of the two samples collected in 2015.

Current exceedances of the SVGW-R are only observed in the property boundary well MW-122 and offsite well MW-553. Although the concentrations of benzene detected in groundwater have been below the residential MSC in the samples collected from MW-553, they exceed the site specific screening values. As such, additional assessment or remedial measures will be required to address this pathway. As there have been exceedances of the screening values along the property boundary for both benzene and 1,24-TMB in

recent years, the vapor intrusion pathway for offsite receptors will be assessed further for these compounds in a future Act 2 deliverable.

7.0 QUALITY ASSURANCE/ QUALITY CONTROL

Methods established by Evergreen to examine data quality are outlined in **Appendix E**, *Quality Assurance/Quality Control Plan and Field Procedures Manual*. All fieldwork conducted as part of the site characterization activities was performed in accordance with the procedures outlined in the *Field Procedures Manual*, **Appendix E**. An assessment of analytical data collected as part of this investigation under the *Quality Assurance/Quality Control Plan* is included in **Appendix K**. The following sections describe specific aspects of quality assurance/quality control procedures that pertain to the activities outlined in this report.

7.1 EQUIPMENT DECONTAMINATION

All sampling equipment was either dedicated or decontaminated in accordance with the field sampling procedures to prevent cross-contamination. Prior to sampling, the equipment was decontaminated with successive rinses of detergent, potable water, and distilled water.

7.2 EQUIPMENT CALIBRATION

Air quality monitors used for both air monitoring and soil screening were calibrated prior to use. Both a zero calibration and a span calibration using gases of known concentration as recommended by the manufacturer (i.e. 100 ppm_v isobutylene for the photoionization sensor) were performed.

7.3 SAMPLE PRESERVATION

Samples were placed directly into chemically preserved and/or non-preserved glassware provided by the analytical laboratory, as appropriate. All samples were preserved and shipped at a temperature of approximately 4° Celsius or less by application of ice prior to shipment to the analytical laboratory. This temperature was maintained during shipment by placing ice in zip-top bags above, around, and below the sample containers.

7.4 DOCUMENTATION

Chain-of-custody forms were maintained throughout the sampling program to document sample acquisition, possession, and analysis. Chain-of-custody documentation accompanied all samples from the field to the laboratory. Each sample was assigned a unique identifier that was recorded in the field notes as well as on the chain-of-custody document.

8.0 QUALITATIVE FATE AND TRANSPORT ASSESSMENT

8.1 SOIL

No fate and transport modeling was completed for the soil analytical results since the soil to-groundwater pathway is evaluated through groundwater data. Potential exposure pathways for AOIs 1 through 4 are discussed in detail in **Section 9**.

8.2 GROUNDWATER

The following sections present a qualitative assessment of contaminant fate and transport, including an evaluation of plume stability, COC trends, and potential impacts to surface water.

8.2.1 Geologic Framework

- The Marcus Hook Industrial Complex occurs within the up-dip edge of the Coastal Plain PhysiographicProvince, approximately one and a half miles southwest of the edge of the Piedmont. The Coastal Plain is defined as having relatively flat topography and as being underlain by a wedge of unconsolidated sediments that thicken in a southeasterly direction atop a sloping bedrock surface.

- As described in **Section 2.2.1**, although the subsurface conditions at the facility above bedrock are locally heterogeneous, the unconsolidated material underlying the facility can be grouped into four general units.

    1. *Anthropogenic fill*: Fill has been reported to be present underlying the entire facility at variable extent and thickness ranging from approximately 1 to 25 feet. The fill composition varies, but generally is composed of one or more of the following: silt, sand, gravel, clay, wood fragments, cinders, apparent dredged material, sludge, spent clay, and other construction/demolition or refinery materials. Portions of the facility that extend beyond the historical Delaware River shoreline of 1937 were generated by filling of the river margin with various refinery-generated materials.
    2. *Recent alluvium ("silty clay layer")*: Underlying the fill are predominantly silty clay sediments referred to as the "silty clay layer". The silty clay layer within the facility consists of micaceous, greenish-gray to dark gray silty clay with minor roots, wood, peat, and other vegetative material, but can vary to include interbedded fine-grained sands, silty sands, clayey silts, and gravels. The silty clay generally has a soft consistency but can become stiff with depth or where sandy. The lithology of the silty clay layer is consistent with what Owens and Minard (1979) describe as Delaware Bay estuarine deposits, an organic-rich estuarine facies consisting of dark colored clayey silts interbedded with fine to very fine sand. The silty clay layer is present beneath most of the facility and generally thickens towards the east and the historical shoreline of 1937. Beneath the facility, the silty clay layer ranges in thickness from approximately 5 to 20 feet.
    3. *Pleistocene Trenton Gravel*: Apparent Trenton gravel deposits underlie the silty clay layer and in places unconformably overlie bedrock at the facility. The Trenton gravel generally ranges in thickness from approximately 2 to 10 feet. The Trenton gravel consists of fine to coarse-grained sand, gravel, sandy silt, and clayey sand. The sand and gravel unit is present throughout much of the facility; however, its thickest deposits vary laterally. The sands and

gravels commonly coarsen with increasing depth. Cobbles may be present at the base of the unit in some areas of the facility, generally along the shoreline of the Delaware River.

4. *Potomac Formation*: On the basis of stratigraphic position and lithology, it appears from test boring data that the Potomac Formation may be present beneath the facility in very limited thickness and areal extent. Where observed, these deposits are generally less than 10 feet in total thickness and appear to occupy a subtle trough in the bedrock surface nearest the Delaware River. Lithologies include pinkish gray to gray clay with a stiff consistency, banded fine sands, peat, and pale brown to yellow fine to medium sand.

Bedrock at the facility has been identified through test boring advancement. Where encountered, a saprolite layer is commonly associated with it that contains a visible rock fabric consistent with published descriptions of Ardentown Granitic Suite crystalline bedrock. Along the northern facility boundary, bedrock was identified near surface beneath a veneer to a few feet of fill. The bedrock surface slopes south and deepens towards the Delaware River. The elevation of the top of crystalline bedrock (including saprolite) at the facility ranges from approximately 30 feet to deeper than -50 feet NAVD 88.

8.3 HYDROGEOLOGY

As discussed in **Section 2.3.2** of this report, groundwater occurs in the unconsolidated sediments overlying bedrock at the facility. The aquifer consists of the saturated portions of the fill, alluvium, and Trenton "gravel." Although semi-confined conditions occur locally, the aquifer at the facility is generally considered to be unconfined. Due to the highly variable nature of the composition of the unconfined aquifer, hydraulic conductivity (k) values are expected to also be highly variable. Available aquifer testing for AOIs 1 through 4 shows k values ranging from 1.3 feet per day (ft/d) in MW-29 (AOI 3) to 19.7 ft/day in a former well (MP-3) which was located in the southwestern corner of AOI 2 near the 12 Plant Separators (Brown and Root, 1993). It is also assumed that areas with higher hydraulic conductivities exist where sand and gravel are present in the saturated zone. Calculations, such as those for the LNAPL mobility term discussed in **Appendix I**, use conservative estimates for hydraulic conductivity (328.10 ft/d for gravel, American Petroleum Institute [API], 2006).

Bedrock underlying the facility is comprised of a medium to coarse grained crystalline member of the Ardentown Granitic Suite. Crystalline bedrock, particularly igneous and high-grade metamorphic rock types such as those associated with the Wilmington Complex, generally has low porosity with little, if any, secondary porosity/permeability yielding poor water-producing capabilities. Therefore, evaluation of contaminant transport within bedrock is not necessary, as it is not considered a potentially complete pathway to a receptor.

The average hydraulic gradient across the facility is 0.007 ft/ft, and groundwater flow is generally towards the southeast in the direction of the Delaware River. As discussed in **Section 2.3.2**, localized areas exhibiting steeper gradients occur in northern AOI 1, western AOI3, and southern AOI 4. Although flow across all four AOIs is generally toward the Delaware River, the eastern portions of AOI 3, and AOI 2 to a lesser extent, show evidence of a more easterly component of flow near the site boundary at Green Street.

8.4 HYDROLOGY AND TOPOGRAPHY

- LiDAR (USGS, 2010) indicates that present-day topography is relatively flat across the facility, rising gently to the north from approximately 6 feet along the bank of the Delaware River to approximately 60 feet along Ridge Road (NAVD 88). Just north of the facility, steeper topography is apparent. Storm water sheet flow follows topography and generally flows southeast across the property towards the Delaware River.

- Within AOIs 1 through 4, much of the surface area present is impervious or assumed to be of limited permeability.

- The Delaware River lies directly adjacent to the southeastern boundary of AOI 3.

- National Weather Service Online Weather Data (NOWData) for Philadelphia, Pennsylvania, indicates that since 1872, mean annual precipitation is approximately 42 inches (ranging from approximately 29 to 64 inches). Precipitation for Marcus Hook, Pennsylvania is assumed to be similar.

- Stormwater runoff within AOIs 1 through 4 is managed by the onsite storm sewer system as described in **Section 2.3.1**. Storm water is diverted to an onsite treatment facility which discharges to the publicly owned treatment facility at the DELCORA. This present-day storm sewer system generally runs in the former beds of Walker's Run and Middle Creek.

- Natural recharge of the unconfined aquifer beneath AOIs 1 through 4 and proximity is assumed to be spatially variable but limited in overall capacity as a result of the high percentage of impervious surface coverage present and the fine-grained nature and extent of recent alluvial deposits above the water table.

8.5 ANTHROPOGENIC FEATURES

8.5.1 Historical Fill

Anthropogenic fill is present beneath the existing land surface at most locations in AOIs 1 through 4 in thicknesses ranging from approximately 1 to 25 feet. The fill composition varies, but generally is composed of one or more of the following: silt, sand, gravel, clay, wood fragments, cinders, apparent dredged material, sludge, spent clay, and other construction/demolition or refinery materials. Portions of the facility that extend beyond the historical Delaware River shoreline of 1937 were generated by filling of the river margin with various refinery-generated materials.

8.5.2 84-inch Storm Sewer

Although numerous utilities are present in the subsurface beneath AOs 1 through 4, the 84-inch storm sewer that runs generally parallel to Greet Street may be of particular significance in the context of an

evaluation of contaminant fate and transport due to its location, elevation, and size. The sewer runs approximately parallel to Green Street on the site from the middle of AOI 1 to its discharge point at the Delaware River in AOI 3 (**Figure 1-2**) . The sewer has several laterals that branch off to the northeast. Due to its proximity to the occurrence of LNAPL in the area near Green Street between approximately 2nd Street and 4th Street, GES performed investigation of the construction in this portion of the property in 1995. In this location, the sewer was built in 1977 and is constructed of corrugated galvanized pipe (GES, 1995). Multiple trenches were performed along the sewer to investigate its relationship to groundwater and LNAPL in the area. The top of the sewer was observed between 3 and 10 ft bgs, and is located at elevations crossing the water table.

8.5.3 Active Remediation Systems

There are no active remediation systems in AOI 1 or AOI 2. In AOI 3, there are 2 active remediation systems (Laboratory Building Remediation System and Green Street Remediation System). In AOI 4, there are 2 active remediation systems (H-5/Post Road Remediation System and 12 Tank Remediation System). **Figure 1-2** shows the location of the active remediation systems and **Appendix J** provides a detailed discussion of each of the systems. System design, operation, and totalized fluid recovery can be summarized as follows:

<u>Laboratory Building Remediation System</u>

- Constructed in 1995 as a dual-phase recovery system drawing from recovery wells RW-5, RW-6, and RW-7.
- Located on the north side of the Laboratory Building to dewater the basement area of the building and prevent migration of LNAPL and hydrocarbon vapors into the building.
- Recovery wells RW-134 and RW-135 were added on the south side of the Laboratory Building in 2001.
- The system was modified in 2015/2016 and consists of a network of pre-existing and newly installed recovery wells: RW-5, RW-6, RW-7, RW-29, RW-30, RW-31, RW-32, RW-134, and RW-135.
- The goal of the current system is multi-phase recovery of LNAPL, groundwater, and hydrocarbon vapors surrounding the Laboratory Building, Main Office Building, and vicinity.
- Total fluids are extracted by pneumatic pumps utilizing plant-supplied air and passed through an oil/water separator. Recovered groundwater is conveyed to the facility's wastewater treatment plant. Recovered LNAPL is gravity drained from the oil/water separator into two 550-gallon holding tanks in series that are periodically pumped out and the contents recycled at the facility.
- Vapors are extracted from the recovery wells via a regenerative blower, and are then passed through a vapor liquid separator, and then into an electric catalytic oxidizer.
- Since its inception, the Laboratory Building Remediation System has recovered approximately 118,374,459 gallons of total fluids and 112,405 gallons of LNAPL (through September 2016).

<u>Green Street Remediation System</u>

- Consists of a recovery well network installed in 1998 within an approximately 325 foot long product interception trench, which is located along the western side of AOI 3 near the intersection of Green Street and 3rd Street.

- Is a LNAPL skimming system installed in 1998 that was designed to mitigate potential LNAPL migration beyond the perimeter of the facility, and to mitigate potential LNAPL impact to the nearby 84-inch storm sewer.
- Pneumatic skimming pumps are installed in 5 wells (S-1, S-2, S-3, SS-1A(new), and P-3), passive bailers are installed in 2 wells (S-4 and P-5), and absorbent wicks are present in 2 wells (P-1 and P-2).
- Recovery wells are gauged on a weekly basis; pumps are turned on/off as needed based on recoverable product thickness accumulations in each well.
- Recovered LNAPL is stored in a 1,100-gallon holding tank which is periodically pumped out and the contents recycled at the facility.
- Since its inception, the Green Street Remediation System has recovered approximately 31,980 gallons of LNAPL (through September 2016).

H-5/Post Road Remediation System

- As originally designed, the system consisted of two recovery wells (RW-3 and RW-4) designed to recover total fluids for the purpose of mitigating the potential migration of LNAPL into nearby utility conduits, and to eliminate surface ponding during storm events.
- The recovery wells of the present day system include a set of wells referred to as the Post Road wells (RW-4, RW-150, RW-151, RW-152, RW-155, RW-156, RW-157, RW-201) and the H-5 Control Room wells (RW-247, RW-248, RW-249, RW-251, RW-252, RW-253, RW-254, and RW-255). The Post Road wells are utilized for total fluids recovery while the H-5 Control Room wells recover total fluids and vapors. Recovered total fluids are discharged to a benzene NESHAP controlled sewer.
- The SVE component of the current system configuration consists of a sub-floor blower in addition to vapor recovery from wells RW-247, RW-248, RW-249, RW-251, RW-252, RW-253, RW-254 and RW-255. The H-5 Control Room SVE system has operated from 2013 through 2009 and from 2011 to present.
- Historic recovery totals for the H-5/Post Road Remediation System are 6,268,070 gallons of total fluids and 31,709 gallons of LNAPL (through September 2016).

12 Tank Remediation System

- Operation of the system commenced in October 2001 and was designed to recover total fluids from nine recovery wells (RW-3, RW-147, RW-148, RW-149, RW-160, RW-161, RW-162, RW-164, and RW-165) in the vicinity of 12 Tank.
- In 2013, the system was upgraded to include pneumatic total fluids pumps in 13 recovery wells (RW-3, RW-16, RW-17, RW-18, RW-147, RW-148, RW-160, RW-161, RW-162, RW-163, RW-164, RW-165, and RW-272) located on the west and south sides of 12 Tank, along Hewes Avenue and Post Road.
- Pneumatic submersible pumps recover groundwater and LNAPL, using facility-supplied air, and total fluids are passed through an oil/water separator. Recovered groundwater is pumped through a facility line to the Middle Creek Conveyance process sewer line southeast of 254 Tank and recovered LNAPL is stored in a 550-gallon holding tank that is periodically pumped out and processed through the facility's slop oil system.
- The original SVE system was reconfigured in 2013 to incorporate seven wells (MW-199, MW-200, RW-3, RW-147, RW-148, RW-160, and RW-161) around 12 Tank. The SVE system was restarted in

September 2014 in response to concentrations of VOCs in the utility manholes along Post Road. Vapors are recovered from the SVE system utilizing a regenerative blower. The effluent from the regenerative blower passes through a humidifier prior to entering the biofilter bed.

- The 12 Tank Remediation System has operated from 2001 through 2006, from 2008 through 2009, and from July 2014 to present.
- Historic recovery totals for the 12 Tank Remediation System are 2,592,967 gallons of total fluids and 35,557 gallons of LNAPL (through September 2016).

8.5.4 Inactive Remediation Systems

There are no inactive remediation systems in AOI 1 or AOI 2. In AOI 3, the Main Office Building Area Recovery System was incorporated into the Laboratory Building Remediation System as detailed in **Section 8.5.3** and **Appendix J**. In AOI 4, there are 2 inactive remediation systems (Auto Lab Remediation System and Storehouse Area Recovery System). System design, operation, and totalized fluid recovery can be summarized as follows:

Main Office Building Area Recovery System

- In August 2004, eleven monitoring wells were installed around the Main Office Building. These wells were intended to act as LNAPL delineation wells and LNAPL extraction wells where practicable.
- Recovery from MW-266 began in June 2005 using a pneumatic LNAPL skimming system, which was moved to MW-80 shortly thereafter.
- Information could not be located on recovery totals from inception through the first half of 2005. However, 234 gallons of LNAPL were recovered during the 3rd quarter of 2005 and 149 gallons of LNAPL were recovered during the 4th quarter of 2005 from MW-80. The system was turned off in the winter of 2005 and no additional product was recovered from MW-80 or MW-266.
- In February 2014, RW-30 was installed in the vicinity of MW-80 and MW-266. RW-30 is currently an active recovery well for the Laboratory Building Remediation System.

Auto Lab Remediation System

- This system was installed and started January/February of 2002 and consisted of total fluids and vapor recovery at wells RW-159, RW-166, RW-167, RW-168, and RW-169.
- The system was taken offline June 12, 2003, due to absence of recoverable LNAPL at the system's wells and the system did not operate from 2003 to 2013.
- The system operated from April 2013 through July 2014 for total fluids recovery due to groundwater observed in the utility manholes along Post Road and surface ponding of water at the manhole adjacent to the Braskem facility. Recovered fluids were discharged to a controlled sewer [National Emissions Standards for Hazardous Air Pollutants (NESHAP) for benzene].
- Presently, operation of the Auto Lab System is not required as the nearby 12 Tank System has continued to provide adequate drawdown of groundwater along Post Road.
- During its lifetime, the Auto Lab Remediation system recovered approximately 48,720 gallons of total fluids and 347 gallons of LNAPL (through September 2016).

Storehouse Area Recovery System

- Consisted of 2 recovery wells, RW-236 and RW-238 along Post Road, which are located to the east of 12 Tank Remediation System. The recovery wells were installed in 2000 and the recovery system was started in September 2002.
- The system was constructed for dual-phase recovery of total fluids and SVE. The recovered ground water was pumped to a refinery sewer that discharged to the refinery separator. Recovered LNAPL gravity drained from an oil/water separator to a 550 gallon holding tank that was periodically pumped out. Recovered product was recycled by the refinery. The extracted vapors are treated through a 1,000-pound carbon adsorber prior to discharge to the atmosphere.
- The total fluids portion of the system operated until August 2004 and the SVE system operated through October 2004. The Storehouse Area Recovery System was shut-down on December 13, 2004 due to the absence of recoverable LNAPL.
- The lifetime recovery totals for the system were 109 gallons of LNAPL and 14,920 gallons of total fluids.

8.6 GROUNDWATER CONSTITUENTS OF CONCERN

The table below summarizes the COCs that were detected at concentrations above the SHS in groundwater during the characterization sampling events (see **Table 4-2** for additional detail). Compounds detected above the SHS, only in sub-LNAPL groundwater samples are indicated by "SL".

	AOI 1	AOI 2	AOI 3	AOI 4
Benzene	x	x	x	x
EDB			x	x
EDC				x
Ethylbenzene	x			x
MTBE	x	x	x	x
Toluene	x			x
1,2,4-TMB	x		SL	x
Xylenes				x
Anthracene			SL	
Benzo(a)anthracene			SL	
Benzo(a)pyrene		x	x	x
Benzo(b)fluoranthene			SL	x
Benzo(g,h,i)perylene		x	x	x
Benzo(k)fluoranthene			x	
Bis(2-ethylhexyl)phthalate			x	
Chrysene		x	SL	x
2-Methylnaphthalene			SL	
Naphthalene	x		SL	x
Pyrene			SL	x
Quinoline			SL	x
Arsenic	x	x		
Chromium		x		
Lead		x	x	x
Selenium		x		
Silver		x		
Vanadium			x	x
Zinc			x	

Available historical analytical data from previous groundwater sampling events (pre-2013) were reviewed by Stantec. These data indicate the following additional COCs were identified at concentrations in excess of the current SHS during past groundwater sampling events: phenanthrene, mercury, cobalt, and barium. Historically, some COCs listed in the summary table above have also been detected in exceedance of the current SHS in AOIs other than those indicated in this table which summarizes only groundwater data from samples collected since 2013.

8.7 GROUNDWATER PLUME LOCATIONS

For the purposes of this qualitative assessment of contaminant fate and transport, Stantec evaluated available analytical data from Evergreen's electronic database for results collected during the characterizations of AOIs 1 through 4. As these investigations have covered a large area and, as outlined in **Section 8.6**, there are numerous COCs that have been detected in exceedance of the SHS throughout the AOIs, areal occurrence of exceedances was examined to select COCs that could be used as qualitative-level proxies. These compounds were selected for a variety of reasons including high water solubility, greatest areal extent of impact, and representativeness of areal extent/concentration values. These compounds are listed below along with COCs that are generally found to be distributed in patterns that mirror or are localized within the locations of the proxy compounds.

Proxy: COCs Represented

- **Benzene**: EDB, EDC, ethylbenzene, toluene, quinoline, and xylenes
- **MTBE**
- **1,2,4-TMB**
- **Benzo(a)pyrene**: anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, and 2-methylnapthalene
- **Chrysene**: pyrene
- **Bis(2-ethylhexyl)phthalate**
- **Naphthalene**
- **Arsenic**
- **Lead**: chromium, selenium, and silver
- **Vanadium**

The following discussions of current dissolved phase plumes in AOIs 1 through 4 use these ten proxy COCs to represent all dissolved phase impacts. Isoconcentration maps depicting the distribution of these COCs (maximum concentrations detected between 2014 and first quarter of 2016) are provided in **Figures 8-1 through 8-10**. In addition to data from AOIs 1 through 4, analytical data in neighboring AOIs 5 and 6 are provided to show contaminant distribution across internal AOI boundaries. For certain compounds which have a site-wide groundwater footprint, the isoconcentration plumes were also extended into AOIs 5 and 6, in order to show general extent of groundwater impacts above the SHSs. It should be noted that this additional data set from AOIs 5 and 6 is limited and is included for informational purposes only; a complete data set with further refinement of contaminant plume distributions and related discussions will be presented in the remedial investigation reports for these individual AOIs (currently in progress under Stantec and GHD).

Golden Software's Surfer® 13 was used to interpolate the groundwater COC data using block kriging. Grid residuals were evaluated and the interpolated surfaces were subsequently contoured and imported into a geographic information system (GIS) for display and evaluation. In addition to block kriging, other gridding methods were also evaluated with the goal of generating plume maps which best represented known hydrogeological conditions, contaminant geochemistry, contaminant source areas, as well as the

spatial and statistical distribution of available analytical data. Under these considerations, the natural neighbor gridding method provided reasonable VOC and semi-volatile organic compounds (SVOC) distributions across the facility. The inverse distance to power method was used to generate a grid for lead, which had uneven data distribution with less than 250 observations. Due to limited data points for arsenic (approximately 50 observations), a simple linear point kriging method was used. In some cases, certain assumptions about anisotropy and angle were made based on inferred hydrologic conditions at the facility.

AOI 1

Concentrations of benzene, MTBE, 1,2,4-TMB, naphthalene, and arsenic were detected above their respective SHS values in AOI 1.

- The highest concentrations of benzene, 1,2,4-TMB, and naphthalene are present in wells interior to the property and located in and adjacent to the former 10 Plant processing area (MW-543, MW-546, MW-547, and MW-549). It is assumed that the presence of these constituents in the dissolved phase can be attributed to operation of the 10-4 unit. Concentrations of these constituents exceeding the SHS are delineated in the downgradient direction onsite by monitoring wells MW-297, MW-425 (AOI 4), MW-526, and MW-550.

- Concentrations of MTBE exceeding the SHS are in the southwestern portion of the AOI, and higher concentrations of MTBE are present to the southwest in AOI 4 (highest concentration in MW-506). This is generally in the side-gradient direction. MTBE exceedances in this area are delineated in the downgradient direction in AOI 1 by MW-526 and MW-547.

- Concentrations of arsenic exceeding the SHS are primarily present along the southeastern AOI boundary adjacent to the Amtrak/Norfolk Southern Railway (MW-526, MW-547, and MW-550), but were also detected further north in MW-543. There is a general correlation between elevated VOC concentrations and arsenic exceedances in AOI 1. The presence of dissolved hydrocarbons may be causing the reduction of iron hydroxides in soils, which in turn releases naturally-occurring, solid state arsenic into groundwater, a process described in Cozzarelli et al. (2016). Concentrations of arsenic exceeding the SHS in this area are delineated in AOI 4 by samples collected from MW-298, MW-429, and MW-425.

AOI 2

Concentrations of benzene, MTBE, benzo(a)pyrene, chrysene, arsenic, and lead were detected above their respective SHS values in AOI 2.

- Concentrations of benzene and MTBE above the SHS occurred in the west-central portion of the AOI within the 12 Plant Sludge Basin (SWMU 25). In addition, marginal exceedances of estimated chrysene detections are found in two wells, MW-512 and MW-518, also in the 12 Plant Sludge Basin. Hydrocarbons associated with the sludge in this area are the likely source of these dissolved phase constituents.

- Elevated MTBE was also detected in the southwester corner of AOI 2 (MW-519 and MW-520). The source of these concentrations is not immediately apparent. It may be associated with the

12A oil/water separator or an unknown source, such as product piping, located within AOI 2 or upgradient.

- Benzo(a)pyrene was detected at concentrations exceeding the SHS in MW-484 and MW-485 located in the northeast corner of the AOI, near the confluence of AOIs 2, 4, and 5. One estimated chrysene exceedance (MW-485) is also located in this area. As discussed below in AOI 4, there are several occurrences of SVOCs detected above the SHS along Post Road in proximity to where LNAPL is present.

- Elevated concentrations of dissolved arsenic and lead are centered over the 12 Plant Sludge Basin. Due to the low pH in groundwater associated with the occurrence of acid sludge in this area, elevated concentrations of dissolved metals would be expected as a result of leaching of naturally-occurring metals.

- No concentrations of COCs were detected in wells located along the northeastern property boundary which is located side gradient to downgradient.

AOI 3

Concentrations of benzene, MTBE, 1,2,4-TMB, chrysene, bis(2-ethylhexyl)phthalate, benzo(a)pyrene, naphthalene, and vanadium were detected above their respective SHS values in AOI 3.

- The highest concentrations of COCs detected in AOI 3 generally coincide with sub-LNAPL groundwater samples collected from MW-33 (highest 1,2,4-TMB and SVOCs), MW-491 (highest MTBE), and MW-492 (highest benzene). This indicates that, in general, the source of VOCs and SVOCs in groundwater in AOI 3 is dissolution from LNAPL plumes. Configurations of dissolved phase plumes also generally correlate with the configurations of LNAPL plumes.

- The majority of the detections above the SHS are interior to the property boundary, with the exception of benzene. Benzene was detected at concentrations exceeding the SHS in MW-122, which is located along Green Street. These exceedences of benzene are delineated by downgradient offsite well MW-553. Benzene has also been intermittently detected in exceedance of the SHS in MW-30 located along the Delaware River.

- Benzo(a)pyrene exceedances are limited to within the property boundary, with the highest concentration observed in MW-33, located at the western boundary of AOI 3. Other marginal exceedances are detected in select wells located in the northern half of AOI 3. These exceedances are delineated within the property; to the east by wells along the property boundary at Green Street; to the north by wells located in southern AOI 2; and to the south by recovery wells north of the R & D building and MW-489.

- Concentrations of bis (2-ethylhexyl) phthalate exceeding the SHS are generally centered in the northern section of the AOI near the Green Street Recovery System, coinciding with the LNAPL present in this area. There was also one recent detection of bis(2-ethylhexyl)phthalate above the SHS in MW-29 located along the Delaware River.

- Concentrations of vanadium exceeding the SHS were detected in three monitoring wells in AOI 3, SP-1B, MW-126, and MW-495. MW-126 and MW-495 are located interior to the AOI, south of the Main Office Building and near the AOI 2 boundary, respectively. SP-1B is located near the property boundary at Green Street; however, the exceedences of vanadium in groundwater are delineated by offsite wells to the east of Green Street (MW-496, MW-497, and MW-498.

- No other COCs are detected above the SHS at the downgradient property boundaries (Green Street boundary and the Delaware River).

- There was one detection of lead slightly above the SHS of 5 µg/L, at 7.6 µg/L, in offsite well MW-553. This isolated exceedance does not occur adjacent to onsite plumes.

- Zinc has been detected in offsite monitoring well MW-497 at concentrations an order of magnitude higher than the SHS during sampling events conducted in June 2015 (79,800 µg/L) and July 2015 (25,400 µg/L and 30,000 µg/L in a duplicate sample). The event in July was conducted to confirm the results from June. Zinc has not been detected in any onsite monitoring wells in exceedance of the SHS, and it is assumed these concentrations are from an offsite source. The next highest concentration of zinc detected in the AOI 3 monitoring program was in offsite well MW-553 (667 µg/L), and the highest concentration of zinc detected onsite was in MW-506 in AOI 4 (103 µg/L).

AOI 4

Concentrations of benzene, MTBE, 1,2,4-TMB, benzo(a)pyrene, chrysene, naphthalene, lead, and vanadium were detected in exceedance of the SHS in AOI 4.

- There are five primary source areas that contain elevated concentrations of combinations of benzene, MTBE, 1,2,4-TMB, and naphthalene. These plume cores are centered around MW-415 (benzene, 1,2,4-TMB, and naphthalene), MW-420 (MTBE), MW-423 (benzene, 1,2,4-TMB, and naphthalene), MW-506 (benzene and MTBE) and MW-508 (benzene, MTBE, 1,2,4-TMB, and naphthalene). Of particular note are the concentrations of MTBE in MW-420 (4 orders of magnitude higher than the SHS) and the concentrations of benzene and 1,2,4-TMB in MW-423 (2 to 3 orders of magnitude higher than the SHS). Exceedances of MTBE, 1,2,4-TMB, and naphthalene are delineated downgradient within AOI 4. Concentrations of benzene exceeding the SHS are detected in some areas of AOI 5, downgradient of the AOI 4 plumes. However, these elevated concentrations may be from distinct source areas located within AOI 5.

- Some of these areas of elevated concentrations in groundwater coincide with documented releases and/or impacts to soil as indicated by direct contact exceedances as described in **Section 3.4**. MW-415 is in the area of the release in H-7 area, north of the clay treater (**Section 3.4.4**). MW-423 is located in the containment area for Tank 242. There were direct contact standard exceedances in the soil boring for this well (1,2,4-TMB). In one of the soil borings completed in the area, AOI4_BH-15-37, elevated concentrations of MTBE aove the SHS but below the non-residential direct contact MSCs were detected in the soil samples (1,150 mg/kg at 0-2 ft bgs and

4,120 mg/kg at 2-4 ft bgs). Considering the high solubility of MTBE, these high concentrations detected in soil boring AOI4_BH-15-37 are likely in the vicinity of the source.

- Elevated benzo(a)pyrene concentrations were detected in three distinct areas around the southern boundary of AOI 4 with AOIs 2 and 5. One of these areas coincides with elevated concentrations of chrysene. As mentioned in the discussion of dissolved phase plumes in AOI 2, these SVOC exceedances along Post Road are in proximity to where LNAPL is present; therefore, it is assumed the LNAPL is the source of these dissolved compounds.

- Lead was detected at concentrations exceeding the SHS in three distinct areas; along the eastern boundary of the northern section of AOI 4 (MW-136 and MW-403), along the southern boundary to the east (MW-426), and along the southern boundary to the west (MW-357 and MW-354). In the northern corner, the slight exceedence of the SHS (7.7 µg/L) may be attributable to tank farm operations; there is a slop oil tank (Tank 23) located nearby to the southwest. This exceedance is isolated to one well and is delineated within the property. The other two plumes located along the southern boundary of AOI 4 are likely attributable to operations related to product storage and blending activities historically conducted in AOI 4. These exceedances are delineated in the downgradient direction through groundwater data collected in AOI5.

- Vanadium was detected at concentrations exceeding the SHS in two wells in AOI 4, MW-390 and MW-403. MW-390 is located in the Upper No. 1 Tank Farm West Section, and MW-403 is located in the Upper No. 1 Tank Farm, in the northern corner of AOI 4. Both of these exceedances appear to be isolated and are delineated in the downgradient direction.

8.8 GROUNDWATER PLUME STABILITY ASSESSMENT

To qualitatively assess the stability of the identified groundwater plumes, available historical groundwater analytical results were analyzed. Stantec utilized concentration plots (**Figures 8-11** through **8-14**) to evaluate overall plume size and COC concentration trends. The monitoring well network has increased significantly since the initiation of the remedial investigation phase work in 2013. It is likely that many of the plume areas we see currently, particularly in AOIs 1, 2, and 4, where well coverage was sparse, may have existed historically. Prior to the expansion of the well network, the two main sources of groundwater analytical data available were: the site-wide event performed in 2011 in preparation for the submittal of the CCR (Langan, 2012a) and annual perimeter groundwater sampling events that have been conducted since the mid-1990s. The data from the annual perimeter sampling events contain the longest history of groundwater analytical results and, by its nature, represents the general outer edges of the property and some dissolved phase plumes. All wells with greater than five years of historical results and more than five data points were examined for trends.

Historically, there have been relatively few detections of COCs in the wells monitored at the property boundary. Discernible long term trends over the record of sampling have been found for benzene, MTBE, arsenic and lead. **Figures 8-11** through **8-14** show concentration trends for these four compounds in these wells. On the whole, these plots show decreasing trends with the majority of data being below the

SHS at the site boundary in since 2013. The exceptions to this generalization are benzene and MTBE in MW-8, located downgradient of the plume observed at MW-420, but interior to the facility.

Historically, concentrations of benzene in MW-8 were below the SHS with the exception of one sample collected in 2001. Concentrations of benzene are above the SHS in 2013 and 2016, with a low detection in between these sampling events (2014). A clear trend is difficult to discern here. Historical data show MTBE concentrations have decreased from a maximum detected in 2002, to generally stable concentrations near the SHS of 20 µg/L since about 2009, with concentrations fluctuating between 9.1 and 32.7 µg/L.

In summary, although there is minimal historical data in some source areas, there is significant groundwater data available at the property boundary to support the conclusion that, with few exceptions, releases of COCs that have occurred within the facility are not migrating offsite in concentrations exceeding the SHS.

8.9 ISOLATED COC OCCURENCE

There is an isolated historical occurrence of of mercury in groundwater in the area of the mecury release described in **Section 3.3.4**. In this area of AOI 3, two wells were installed, GMP-3 and GMP-6, that have since been destroyed. These two wells were sampled for mercury in 2000 and 2001. Concentrations detected in 2000 were over 4,000 µg/L, above the SHS of 2 µg/L. When sampling was conducted in 2001, concentrations were approximately 3 µg/L. During remedial investigation activities, as discussed in **Section 4.4**, wells (MW-284, MW-286, MW-287 MW-487, MW-490, MW-494, and MW-503) installed in this area and downgradient were sampled for mercury. Detections of mercury in exceedance of the SHS were not observed.

8.10 POTENTIAL ONSITE AND OFFSITE RECEPTORS

Based on the identified impacts to groundwater in AOIs 1 through 4, Stantec has evaluated the following as potential receptors.

- Vapor intrusion affecting potential occupants of buildings in AOIs 1 through 4 was evaluated. In AOI 3, the sample from the Fire House office (AOI3_AI-05) 1,2,4-TMB was detected above the EPA RSLs TR=1E-5, and 1,3,5-TMB was detected above the SVIA-NR SSS. Two samples collected in the H-5 Building (Control Room and Decom Room) of AOI 4 during the heating season (Feburay 4, 2015) exhibited concentrations of COCs (benzene) above the EPA RSLs, TR=1E-5. Naphthalene and 1,2,4-TMB were detected above their respective EPA RSLs, TR=1E-5 in three samples and one dulplicate sample collected in the H-5 Building (Control Room, Decom Room, and Office2 (August 8, 2013)). No other concentrations of COCs were detected above the EPA RSLs, TR=1E-5 in the indoor air samples.
- Infiltration of groundwater into underground utilities has the potential to generate vapors along subsurface corridors. Options to address these potential preferential pathways will be addressed in the Cleanup Plan.

- Direct vapor migration into the vadose zone is also a potential pathway of concern. Concentrations of VOCs at the property boundary and offsite were screened against the SVGW-R and exceedances have included benzene and 1,24-TMB in recent years. The vapor intrusion pathway for offsite receptors will be assessed further for these compounds in a future Act 2 deliverable.
- Other potential receptors for volatilization of constituents in groundwater were not identified within the specified proximity distances that warranted further vapor intrusion evaluation.
- The Delaware River is adjacent to AOI 3, and dissolved COCs could potentially migrate from groundwater to surface water. Although concentrations of COCs detected in monitoring wells located along the Delware River (MW-28, MW-29, MW-30, and MW-502) have rarely been detected at concentrations exceeding the SHS, the potential impact to surface water will be further evaluated through a CORMIX Mixing Zone Model (CORMIX) that will be presented in the Cleanup Plan. Cumulative loading of COCs from groundwater to surface water will be evaluated with human consumption of fish designated as the exposure pathway of concern.
- No known potable water supply wells exist at or in close proximity to AOIs 1 through 4. The results of a well search using the Pennsylvania Groundwater Information System (PaGWIS) database is included in **Appendix L**.
- Bedrock underlying the facility is comprised of a medium to coarse grained crystalline member of the Ardentown Granitic Suite. Crystalline rocks generally have no porosity with little, if any, secondary porosity yielding poor water producing qualities. Therefore, evaluation of contaminant transport within bedrock is not necessary, as it is not considered a potentially complete pathway to a receptor.

9.0 ECOLOGICAL ASSESSMENT

On August 10, 2015, a survey of endangered, threatened, and special concern species and habitat was conducted by submitting a request to the Pennsylvania Natural Diversity Inventory (PNDI) database. The PNDI search identified no known impact results from the U.S. Fish and Wildlife Service. The PNDI search identified potential threatened and endangered species impacts that required further review by the Pennsylvania Game Commission, the Pennsylvania Department of Conservation and Natural Resources (PA DCNR), and the Pennsylvania Fish and Boat Commission (PAFBC). Stantec submitted consultation letters to the PA Game Commission, PA DCNR, and the PAFBC on September 8, 2015 to request further investigation and clearance based on ecological impact potential. Responses indicating that no adverse impacts are expected to species or habitats of special concern were received from the PA Game Commission on September 11, 2015, the PAFBC on September 29, 2015 and from PA DCNR on October 2, 2015. The PNDI search and agency response letters are valid for two years. All PNDI documentation is included in **Appendix M**.

The majority of AOIs 1-4 is covered with impervious surfaces, soil, or gravel. The soil and gravel-covered areas of AOIs 1-4 are not likely to serve as a breeding area, migratory stopover, or primary habitat for wildlife. The U.S. Fish and Wildlife Service National Wetlands Inventory online mapping tool was consulted to assist in identification of wetlands at the site (**Appendix M**). The only wetland identified by the mapping tool shows a freshwater pond which occupies a former tank berm located in AOI 4 to the northeast of Tank 213. This wetland does not meet any of the criteria listed in 25 PA Code §105.17(1) and therefore, is not categorized as an exceptional value wetland. No other wetlands have been identified in AOI 1-4.

No threatened species, endangered species, habitats of concern, or species of concern were identified through the use of the PNDI search and follow up agency correspondence, and no exceptional value wetlands exist within AOIs 1-4. Therefore no additional ecological assessment is waranted.

10.0 CONCEPTUAL SITE MODEL

Through comprehensive file review and characterization activities performed as a part of this RIR, Stantec's conceptual understanding of the present conditions identified at AOIs 1-4 is summarized as follows.

10.1 DESCRIPTION AND SITE USE

- The subject property is located on the north bank of the Delaware River in the Borough of Marcus Hook, Delaware County, Pennsylvania, with portions of the facility in Lower Chichester Township, Pennsylvania and Claymont, New Castle County, Delaware (See **Figure 1-2**). The facility, which is located on industrial property, covers approximately 585 acres of land with access restricted by fencing and security measures. Current operations at the facility consist of the processing and storage of light hydrocarbon products plus support facilities.

- The area surrounding the subject property is characterized by a mixture of residential, commercial, recreational, active industrial, and vacant industrial properties.

- The facility has a long history of transportation, storage, and refining of fuels and petrochemicals with operations beginning in 1902 by Sun Oil. The property was transferred from Sunoco, Inc. (R&M) to SPMT in 2012 at which time the transition from a refinery to the current industrial complex operations commenced.

- At the time of this report, the facility is undergoing major redevelopment in association with shale gas related projects and other infrastructure changes.

- AOI 1 historically contained the 10-4 Catalytic Cracking Unit which split long chain hydrocarbons into high octane compounds for gasoline and fuel oil blending. The unit has been decommissioned, and all associated infrastructure was demolished in 2014 and 2015. The area currently serves as a storage/lay down area for ongoing infrastructure projects.

- Historically, AOI 2 consisted mainly of the 12-3 Crude Unit which processed crude via atmospheric and vacuum distillation. The unit was demolished in 2014 and 2015, and the area is currently used as a parking lot for facility contractors. Other main features of AOI 2 are the Sunoco Race Fuels facility in the northern portion of the AOI, and the 12 Plant Sludge Basin located along the western boundary of the AOI which consists of an unlined basin used for the disposal of acid sludge and tar in the 1920s through the 1940s.

- AOI 3 mainly consists of facility office buildings which are located in the southern portion of the AOI. Historically, the northern part of the AOI did contain some product handling areas including ASTs and the 8-C Crude Unit which processed crude via atmospheric distillation and vacuum distillation. The facility office buildings are still present, although several buildings are unoccupied.

- AOI 4 has historically consisted of several tank farms. The H-5 Plant Unit, a gasoline blending plant, is located in the southeast portion of the AOI. Since Suncoco Partners obtained the property in 2012, many of the storage tanks have been taken out of service or permenantly decommissioned via removal or closure-in-place. The H-5 Plant Unit is still in operation.

10.2 GEOLOGY

- The Marcus Hook Industrial Complex occurs within the up-dip edge of the Coastal Plain Physiographic Province, approximately one and a half miles southwest of the edge of the Piedmont. The Coastal Plain is defined as having relatively flat topography and as being underlain by a wedge of unconsolidated sediments that thicken in a southeasterly direction atop a sloping bedrock surface. Topography at the facility slopes to the southeast toward the Delaware River.

- As described in **Section 2.2**, although the subsurface conditions at the facility above bedrock are locally heterogeneous, the unconsolidated material underlying the facility can be grouped into four general units: anthropogenic fill, recent alluvium, Trenton "gravel", and Potomac Formation (limited extent).

- Bedrock beneath the facility is identified as the Ardentown Granitic Suite of the Arden Plutonic Supersuite which includes quartz norite, quartz monzonorite, opdalite, and charnockite.

10.3 HYDROGEOLOGY

- Groundwater occurs in the unconsolidated sediments overlying bedrock at the facility. The aquifer consists of the saturated portions of the fill, alluvium, and Trenton "gravel."

- Due to the highly variable nature of the composition of the unconfined aquifer, k values are expected to also be highly variable. When transport calculations are made using k values, conservative values 328.10 ft/d representing gravel were selected.

- The average hydraulic gradient across the facility is is 0.007 ft/ft, and groundwater flow is generally towards the southeast in the direction of the Delaware River. Localized areas exhibiting steeper gradients occur in northern AOI 1, western AOI 3, and southern AOI 4. Although flow across all four AOIs is generally toward the Delaware River, the eastern portions of AOI 3, and AOI 2 to a lesser extent, show evidence of a more easterly component of flow near the site boundary at Green Street.

- Bedrock underlying the facility is comprised of a medium to coarse grained crystalline member of the Ardentown Granitic Suite. Crystalline rocks generally have no porosity with little, if any, secondary porosity which results in low hydraulic conductivities.

10.4 COMPOUNDS OF CONCERN

10.4.1 Soil

- Soil investigations performed for the remedial investigation targeted potential source areas including open storage tank incident areas, historical releases, product handling and storage locations, and RCRA SWMUs and AOCs. All available historical data were used in the remedial investigation data set.

- Delineation was performed to the higher of the non-residential direct contact MSC and the lead SSS, as concentrations of COCs exceeding these values would require a remedial measure in order to attain a standard under Act 2. Samples were analyzed for the Evergreen Petroleum Short List or the Evergreen Comprehensive List as was deemed appropriate for each potential source area. Some areas also included RCRA metals as COCs.

- COCs were detected above the values listed above at the following locations:
  - AOI2_BH-15-004: vanadium at 0-2 ft bgs (AOI 2)
  - AOI2_BH-15-049: 1,2,4-TMB at 2-4 ft bgs (AOI 2)
  - AOI2_BH-15-055: arsenic at 0-2 ft bgs (AOI 2)
  - MW-519: arsenic at 0-2 ft bgs (AOI 2)
  - AOI3_BH-14-050: vanadium at 0-2 ft bgs (AOI 3)
  - MW-411: 1,2,4-TMB 0-2 ft bgs (AOI 4)
  - MW-423: 1,2,4-TMB 0-2 and 2-4 ft bgs (AOI 4)
  - MW-388: vanadium at 0-2 ft bgs (AOI 4)
  - MW-397: vanadium at 0-2 ft bgs (AOI 4)
  - AOI4-BH-16-09: vanadium at 0-2 ft bgs (AOI 4)
  - AOI4-BH-16-10: vanadium at 0-2 ft bgs (AOI 4)

- Where identified in surface soil to exceed the referenced standards, arsenic, 1,2,4-TMB, and vanadium have been delineated both horizontally and vertically through characterization activities and review of existing soil sample analytical data.

10.4.2 Groundwater

- All non-LNAPL bearing wells were sampled at least twice between 2013 and 2016 as part of the remedial investigation. Groundwater samples were analyzed for the Evergreen Petroleum Short List or the Evergreen Comprehensive List as was deemed appropriate for each potential source area. Some wells also included RCRA metals as COCs.

- Concentrations of the following COCs were detected above the SHS during the characterization groundwater sampling events: benzene, EDB, EDC, ethylbenzene, toluene, 1,2,4-TMB, MTBE, xylenes, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, 2-

methylnaphthalene, naphthalene, pyrene, quinoline, arsenic, chromium, lead, selenium, silver, vanadium, and zinc.

- Prior to 2013, the following COCs were detected at concentrations above the SHS in a few isolated cases: phenanthrene, barium, cobalt, and mercury.

10.4.3 Indoor and Ambient Air

- Indoor and outdoor air sampling events were conducted in the heating season (fall/winter months) when levels of VOCs inside buildings are expected to be higher than during warmer months (spring/summery months).

- Detected concentrations of VOCs in indoor and ambient air were below the EPA RSLs, TR=1E-5 or the SVIA-NR SSS for 1,3,5-TMB, with the exception of 1,2,4-TMB in the Fire House and benzene, naphthalene and 1,2,4-TMB in the H-5 Building.

- Offsite exposure to COCs via vapor intrusion is potentially a pathway of concern. Property boundary and offsite exceedances exceedances of the SVGW-R have included benzene and 1,24-TMB in recent years. The vapor intrusion pathway for offsite receptors, including potential migration along preferential pathways, will be assessed further for these compounds in a future Act 2 deliverable.

10.5 LNAPL DISTRIBUTION AND MOBILITY

- A comprehensive LNAPL Conceptual Site Model (LCSM) was prepared and is included as **Appendix I** of this RIR.

- LNAPL samples collected from site monitoring wells through time have identified the presence of several variably-weathered products and mixtures of products refined from crude oil in the subsurface in AOIs 1 through AOI 4 (**Figure 5-1; Table 5-1**).

- Variability in LNAPL characteristics observed in AOIs 1 through AOI 4 is indicative of multiple product releases at different times with subsequent co-mingling of plumes. Areas of LNAPL are identified and delineated within AOIs 1 through AOI 4 (**Figure 5-3**).

- A review of apparent LNAPL thickness (**Figure 5-2a through Figure 5-2e**) and distribution data through time suggests that overall, LNAPL plumes at the site are not migrating. In general, the vertical thickness of LNAPL as observed in monitoring wells has not been increasing and has not been identified in downgradient portions of the monitoring well network that have historically lacked measureable LNAPL.

- Site-specific values of LNAPL transmissivity based on groundwater recovery ratios indicate that overall, LNAPL at AOI 1 is below the lower limit of practicable recovery. However, additional metrics presented indicate that areas of potentially mobile and practicably recoverable LNAPL are still present at several areas that are distal to, or at the leading edge of, active remediation systems.

- LNAPL observed appears to be stable or decreasing (not migrating) and immobile at most locations along the plume fronts presented. LNAPL areas are continually monitored through routine well gauging. LNAPL present at the AOIs 2 and 3 property boundary is addressed by operation of the Green Street remediation system (**Appendix I**). LNAPL is not observed offsite and delineation of LNAPL is achieved in AOIs 1 through AOI 4 by monitoring wells that have no observed or measurable LNAPL.

10.6 QUALITATIVE FATE AND TRANSPORT

- A soil to groundwater model to evaluate the soil to groundwater pathway was not developed for the qualitative fate and transport assessment presented in this RIR. Rather, a qualitative-level assessment of groundwater data has been completed.

- As the groundwater investigation in AOIs 1 through 4 covered a large area and numerous COCs have been detected in exceedance of the SHS throughout the AOIs, areal occurrence of exceedances was examined to select COCs that could be used as qualitative-level proxies. These compounds were selected for a variety of reasons including high water solubility, greatest areal extent of impact, and representativeness of areal extent/concentration values. Compounds selected to represent all COCs in groundwater were benzene, MTBE, 1,2,4-TMB, benzo(a)pyrene, chrysene, bis(2-ethlyhexyl) phthalate, naphthalene, arsenic, lead, and vanadium.

- Plume distributions are discussed in detail in **Section 8.7**, and, generally consist of several relatively discrete plumes. In the northern AOIs (1 and 4) plumes of dissolved phase VOCs occur in areas of historical product handling and storage. Elevated arsenic is also present in a similar pattern to hyrocarbons within AOI 1. AOI 2 does not seem to be the source of dissolved phase hydrocarbons. The dissolved phase plumes located within AOI 2 are for metals and correspond to the configuration of the 12 Plant Sludge Basin, SWMU 25. Dissolved phase VOC and SVOC plumes within AOI 3 correspond with LNAPL occurrences. There are isolated detections of vanadium within AOI 3 and AOI 4.

- With few exceptions, which will be subsequently described, current concentrations of COCs are delineated to the SHS within the MHIC property boundary. One exception to this is benzene in MW-122, which is delineated by offsite wells on the east side of Green Street, and occasionally in MW-30, which is proximal to the Delaware River. The other exception is vanadium in SP-1B, which is delineated by offsite wells on the east side of Green Street.

- Perimeter groundwater monitoring has been conducted at the MHIC since the mid-1990s. An evaluation of these results, as described in **Section 8.8**, shows decreasing trends over time for COCs where they were detected above reporting limits.

- Some areas may have limited historical data in source areas; however, there is significant groundwater data available at the property boundary to support the conclusion that, with few

exceptions, releases of COCs that have occurred within the facility are not transported offsite in concentrations exceeding the SHS.

10.7 EXPOSURE PATHWAY AND RECEPTOR EVALUATION

In order for a pathway to be considered complete, it must have a source, a transport medium, a receptor, and an exposure route. The following section examines exposure pathways by media in order to identify which routes are potentially complete. The exposure routes of concern that will be evaluated are ingestion, dermal exposure, and inhalation. Onsite workers and the public will be evaluated as receptors. The ecological evaluation, as described in **Section 9.0**, did not identify any ecological receptors of concern.

10.7.1 Soil

- Access to AOIs 1 through 4 is restricted by fencing and security measures implemented by SPMT. This would preclude the public from all potential onsite exposures to soil.

- The soil-to-groundwater pathway is evaluated through the groundwater investigation and /analysis documented in this RIR.

- SMPT is responsible for oversight of contractor safety, and implements PPE and work plan/permitting protocols that mitigate the potential for worker exposure to impacted soil through the direct contact and inhalation exposure pathway. These administrative controls which are implemented through established Safety Standards for the facility include requirements for workers to wear proper PPE and conduct air monitoring when conducting activities that include disturbance of soils (i.e. excavation). This leaves exposure to surface soils (0-2 ft bgs) as the only current potentially complete pathway for dermal exposure to soils by workers. Locations of soils containing concentrations of COCs exceeding the non-residential direct contact MSC, as listed in **Section 10.4.1**, have been delineated, and strategies to remediate these exceedances will be presented in the Cleanup Plan. Therefore, it is anticipated that subsequent to implementation of remedial measures, this exposure pathway will be incomplete.

- Volatilization to indoor air was investigated for occupied buildings onsite. This pathway was evaluated through the collection of indoor air samples as described in **Section 6.1**. Concentrations of volatile COCs were compared to the EPA RSLs, TR=1E-5, as it is anticipated that following remedial measures, volatilization to indoor air will be the only remaining potentially complete pathway. Concentrations of 1,3,5-TMB in indoor air were screened against SVIA-NR SSS because there is not an established EPA RSL for this compound. Concentrations above the screening values were detected in the Fire House building in AOI 3 (1,2,4-TMB and 1,3,5-TMB) and the H-5 Building in AOI 4 (benzene, naphthalene, and 1,2,4-TMB). Laboratory reporting limits for some additional compounds were above the EPA RSLs, TR=1E-5 in some buildings. . Options to address this exposure pathway in this location will be presented in the Cleanup Plan.

10.7.2 Groundwater

- As described in **Section 10.7.1**, volatilization to indoor air is of concern for occupied buildings onsite. Options to address this exposure pathway in the the Fire House and the H-5 Building , where comparison of indoor air sampling results to screening values indicate a potentially complete pathway, will be presented in the Cleanup Plan.

- Due to the potential for offsite transport of COCs via groundwater flow, the volatilization to indoor air pathway was also evaluated for this medium. Infiltration of groundwater into underground utility passageways has the potential to generate vapors along subsurface corridors, or for direct vapor migration into the vadose zone. Concentrations of VOCs at the property boundary were screened against the SVGW-R. Current concentrations of benzene at MW-122 exceed the MSC of 5 µg/L. Concentrations of benzene and 1,2,4-TMB have excceded the SVGW-R in recent years; therefore, the vapor intrusion pathway for offsite receptors will be assessed further for these compounds in a future Act 2 deliverable.

- The presence of preferential pathways, such as the storm sewer maintained by Marcus Hook Borough that connects to the onsite 84-inch sewer at various points along the northeastern site boundary, provides a potential additional transport mechanism for VOCs. It is anticipated that this pathway will be further assessed in a future Act 2 deliverable.

- SHS exceedances of COCs in groundwater are not currently detected at the wells located along the property boundaries with the exception of benzene in MW-122 and occasionally in MW-30. As exceedances are delineated at, or very near to, the property boundary along Green Street, exposure to residential receptors is not of concern. A well search (**Appendix L**) was conducted using the PaGWIS. The search was completed for an area inclusive of approximately 0.5 miles from the downgradient facility property boundary. The search does not identify any potable production wells located downgradient of the facility. Additionally, Marcus Hook Borough and Lower Chichester Township are developed municipalities with established public water service.

- Due to the location of the site along the Delaware River, there is potential for dissolved phase COCs to migrate into surface water. Under 25 PA Code §93.9g (PADEP, 2013), potable water supply is not a protected use of the tidal portions of the Delaware River estuary; therefore, the water ingestion exposure pathway is incomplete. However, human consumption of fish is a pathway of concern. This pathway will be further evaluated in future Act deliverables using CORMIX modeling to back-calculate groundwater screening values from human fish of consumption criteria.

- As described in **Section 10.7.1**, SPMT is responsible for oversight of contractor safety, and implements PPE and work plan/permitting protocols that mitigate the potential for worker exposure to impacted groundwater through the direct contact and inhalation exposure pathway. Similar to worker exposure to impacted subsurface soil, worker contact with groundwater would be eliminated through the implementation of these institutional controls.

10.7.3 LNAPL

- As described in **Section 10.7.1**, volatilization to indoor air is of concern for occupied buildings onsite. Options to address this exposure pathway in the Fire House and the H-5 Building where comparison of indoor air sampling results to screening values indicate a potentially complete pathway, will be presented in the Cleanup Plan.

- As described in **Section 10.7.2**, the presence of preferential pathways, such as the storm sewer maintained by Marcus Hook Borough that connects to the onsite 84-inch sewer at various points along the northeastern site boundary, provides a potential additional transport mechanism for VOCs. Of particular concern is the proximity of LNAPL to the 84-inch sewer along the northeastern boundary of AOI 3. It is anticipated that this pathway will be further assessed in a future Act 2 deliverable.

- Potential volatilization to outdoor air was investigated in LNAPL areas underlying contractor parking lots and in the vicinity of office buildings by collecting representative ambient air samples. Analytical results were compared to EPA RSLs, TR=1E-5, and all results were below theses screening values with the exception of naphthalene in one sample collected in the contractor's parking lot of AOI 3, which was slightly above the screening level of 1.3 µg/m^3 at 1.4 µg/m^3. Due to the conservative nature of using these indoor air screening values for ambient air samples, this detection is not considered to be of concern.

- As described in **Section 10.7.1**, SPMT is responsible for oversight of contractor safety, and implements PPE and work plan/permitting protocols that mitigate the potential for worker exposure to LNAPL through the direct contact and inhalation exposure pathway. Similar to worker exposure to impacted subsurface soil, worker contact with LNAPL would be eliminated through the implementation of these institutional controls.

- With the exception of the Post Road area, which lies between two sections of the facility, all occurrences of LNAPL have been delineated to the MHIC property; therefore, offsite exposure to LNAPL is generally not of concern. The only potential pathway within the Post Road area is vapor exposure to utility workers within utility vaults. As these utility vaults have limited or restricted means for entry or exit, and are not designed for continuous occupancy, they meet the OSHA definition of confined space(s). The utility owners have obligations under OSHA to provide training, procedures, and appropriate personal protective equipment (PPE) for employees working in confined spaces. Considering procedures required as part of OSHA regulations regarding confined space entry, and that none of the concentrations of COCs detected exceeded the OSHA PELs, the pathway for utility worker exposure to vapors is considered incomplete.

10.8 SWMU 25: 12 PLANT SLUDGE BASIN

An investigation of the extent of acid sludge located in the 12 Plant Sludge Basin was conducted during the remedial activities. As described in **Section 3.2.2**, the areal and lateral extent of the acid sludge was defined. Potentially complete pathways for exposure to regulated substances are described in **Section 10.7**. The main potential exposure to regulated substances that could be caused by the presence of acid sludge is via exposure to elevated levels of metals in groundwater. Although elevated levels of dissolved metals were detected in wells in the vicinity of the 12 Plant Sludge Basin area, exceedances of the SHS are delineated within the site boundaries. However, other risks are associated with the presence of acid sludge such as the unstable nature of the material, including potential for sinking, potential for migration, presence of low pH materials, and potential for exposure to acid gas compounds. It is expected that Evergreen will implement remedies to mitigate the risks associated with the presence of the acid sludge within the 12 Plant Sludge Basin and that these remedial options will be presented in the Cleanup Plan.

11.0 COMMUNITY RELATIONS ACTIVITIES

A Community Relations Plan (CRP) that includes public involvement with local residents to inform them of the anticipated investigations and remediation activities was included in the Work Plan. The purpose of the CRP is to provide a mechanism for the community, government officials, and other interested or affected citizens to be informed of onsite activities related to the investigation activities at the MHIC. This plan incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action Program. This report and future Act 2 reports will include the appropriate municipal and public notices in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in a local newspaper. As part of the CRP, Evergreen intends to hold public meetings as necessary in the Borough of Marcus Hook to present the strategy and give status updates of the project.

12.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Stantec has prepared this RIR for AOIs 1 through 4 of the Marcus Hook Industrial Complex to satisfy the requirements under Act 2, as specified under 25 PA Code §250.408 (Remedial Investigation Report). The documented investigation activities were performed in general accordance the Work Plan, and subsequent collaborative work scope meeting with PADEP. The characterization investigations were conducted in support of Evergreen's commitment to remediate legacy environmental impacts that existed at the facility prior to Sunoco, Inc. (R&M)'s transfer to SPMT in 2013. In support of those stated objectives, this report has described a comprehensive evaluation of available historical data pertaining to AOIs 1 through 4, and has documented a remedial investigation strategy that included the collection of a significant amount of subsurface information and analytical data.

The following summarizes the conclusions and recommendations regarding characterization of AOIs 1 through 4.

12.1 SOIL

Arsenic (AOI 2), 1,2,4-TMB (AOIs 2 and 4), and vanadium (AOIs 2, 3, and 4) were identified in surface soil samples at concentrations in excess of the 0-2 ft bgs non-residential direct contact MSC. Where identified in surface soil to exceed the direct contact MSC, these compounds have been delineated horizontally and vertically. Soil from these surface soil "hotspot" locations (AOI2_BH-15-004, AOI2_BH-15-055, AOI3_BH-14-050, AOI 4-BH-16-09, AOI 4-BH-16-10, MW-388, MW-397, MW-411, MW-423, and MW-519) will require further pathway evaluation or a remedial measure in order to attain a standard under Act 2. Strategies to remediate these exceedances, likely via excavation or capping, will be presented in the Cleanup Plan.

1,2,4-TMB (AOI2_BH-15-049 and MW-423) was detected in subsurface soil at concentrations exceeding the 2-15 ft bgs non-residential direct contact MSC. In order to attain a remediation standard for these soils (site-specific standard via pathway elimination), the direct contact exposure would need to be rendered incomplete. As described in **Section 10.7.1**, administrative controls are currently implemented at the site (PPE requirements, workplan/permitting protocols) that would prevent exposure during ground disturbance activities. The Cleanup Plan will further discuss the manner in which these administrative controls will be formalized in an environmental covenant or if the impaced soils will be removed.

12.2 GROUNDWATER

Benzene, EDB, EDC, ethylbenzene, MTBE, toluene, 1,2,4-TMB, xylenes, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, 2-methylnapthalene, naphthalene, pyrene, quinoline, arsenic, chromium, lead, selenium, silver, and vanadium were identified onsite at concentrations in excess of the SHS during characterization sampling activities conducted in AOIs 1 through 4. These COCs have all been delineated to the SHS. Historical data indicate that in addition to those substances, phenanthrene, mercury, cobalt,

and barium were historically detected in exceedance of the SHS previously in these AOIs, but here below the SHS during the characterization groundwater sampling events.

With few exceptions, COCs detected at concentrations exceeding the SHS are limited to the interior of the MHIC property. Wells at the downgradient property boundary along Green Street and the Delaware River, in large part, exhibit concentrations of COCs that are non-detect or below the SHS. There is a long history of groundwater monitoring at the property boundary that shows downward trends of COC concentrations (where they have been detected). The Cleanup Plan will present CORMIX modeling in order to further examine the potential for dissolved phase COCs to migrate to the Delaware River and present a potentially complete exposure pathway via human consumption of fish.

It is expected that the selected remediation standard for dissolved phase COCs in groundwater which exceed the SHS will be the site-specific standard via pathway elimination. The Statewide Health Standard may selected for groundwater COCs which meet or are below the SHS at the points of compliance.

12.3 VAPOR INTRUSION PATHWAY

Concentrations of COCs in indoor and ambient air were evaluated for occupied onsite buildings in AOIs 1 through 4. Observed COC concentrations were below the applicable screening values in all buildings with the exception of 1,2,4-TMB and 1,3,5-TMB in the Fire House and benzene, naphthalene, and 1,2,4-TMB in the H-5 building. Laboratory reporting limits for some additional compounds were above the EPA RSLs, TR=1E-5 in some buildings. Options to address this exposure pathway location will be presented in the Cleanup Plan. Upon completion of remediation activities, it is expected that volatilization to the breathing zone will be the only potentially complete pathway for legacy petroleum impacts in AOIs 1 through 4. As such, EPA RSLs, TR=1E-5 screening values are applicable. Concentrations of 1,3,5-TMB in indoor air were screened against SVIA-NR SSS because there is not an established EPA RSL for this compound. It is noted that this conclusion is dependent upon the remainder of the exposure pathways being eliminated through other remedial activities and controls.

In order to confirm concentrations of COCs detected during the first round of indoor air sampling conducted in March 2015, it is anticipated that a second sampling event will be conducted in the occupied buildings located in AOIs 2 and 3 with results being presented in future Act 2 deliverables. Two sampling rounds have already been conducted in AOI 4. As the concentrations of 1,2,4-TMB and 1,3,5-TMB detected in the Fire House could be related to a background condition, this building will be evaluated further in the Cleanup Plan to determine whether volitalization to indoor air is of concern. Options (i.e. OSHA regulations, modifications to theH-5 soil vapor extraction remediation system) for addressing concentrations of benzene, naphthalene, and 1,2,4-TMB above the EPA RSLs, TR=1E-5 in the H5 Building will be presented in the Cleanup Plan.

The pathway for volatilization to indoor air is of concern for offsite receptors and will be addressed in the Cleanup Plan. Potential for direct volatilization from groundwater to the vadose zone exists for benzene and 1,2,4-TMB and measures to address this potentially complete pathway will be presented in the Cleanup Plan along with options for addressing the potential for vapor migration along preferential pathways.

12.4 LNAPL

LNAPL present in the subsurface at and directly adjacent to AOIs 1 through 4 has been delineated into general plume areas as depicted on **Figure 5-3**. The results of LNAPL sampling have characterized the LNAPL plumes into general categories including light distillates, mixture of light and middle distillates, middle distillates, and heavy distillates. The LNAPL characterization results are indicative of multiple product releases at different times with subsequent commingling of plumes in the subsurface (**Appendix I**).

Data evaluated in this RIR indicates that the the majority of LNAPL in AOIs 1 through 4 is generally not migrating or practicably recoverable. However, LNAPL present at several areas that are distal to active remediation systems, may be mobile, able to migrate, and recoverable. These areas include the downgradient edge of the Laboratory Building Remediation System, MW-25 along the eastern edge of AOI 3, and the Auto Lab area in AOI 4. Active LNAPL recovery system operation and well monitoring along the AOIs 1 through 4 property boundary are ongoing to mitigate and monitor for the potential migration of LNAPL. The LNAPL plumes identified within AOIs 1 through 4 are delineated to the property boundary by onsite wells that are absent of LNAPL.

Opportunities are available for refinement of the LCSM and expansion of LNAPL recovery systems to address the potentially recoverable LNAPL (and dissolved phase contaminants) identified in AOIs 1 through 4. Further consideration of LCSM refinement and LNAPL recovery options will be addressed as part of Cleanup Plan activities.

12.5 SWMU 25: 12 PLANT SLUDGE BASIN

Use of engineering and/or administrative controls will be used to address the presence of acid sludge in the 12 Plant Sludge Basin and will be presented in the Cleanup Plan.

13.0 SIGNATURES

The following parties are participating in the remediation at this time and are seeking relief of liability under Act 2 of 1995.

Jim Oppenheim
PE/Vice President
Evergreen Resources Management Operations

This RIR has been prepared in accordance with the final provisions of Act 2 and the June 8, 2002 Land Recycling Program Technical Guidance Manual.

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